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XVI.

THE DEVELOPMENT OF OSSEOUS FISHES.

I.

THE PELAGIC STAGES OF YOUNG FISHES.

BY

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WITH NINETEEN PLATES.

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THE PELAGIC STAGES OF YOUNG FISHES.

We propose in this memoir to continue the papers on the Young Stages of Osseous Fishes commenced by Mr. Agassiz in 1877. We shall take up in succession different points of interest in the development of the bony fishes, devoting the successive numbers of this investigation to limited subjects. The first part of Mr. Agassiz's papers treated of the Development of the Tail.* The second part was devoted to the Development of Flounders,† mainly to the changes of form they undergo while passing from a symmetrical to an asymmetrical stage. The third part ‡ gave a number of sketches of the changes undergone after hatching by some of the more common of the marine fishes of the southern coast of New England. The fourth part of these investigations, by Agassiz and Whitman, § was devoted to a preliminary notice on the early stages of some of the pelagic fish eggs of Newport Bay.||

* A. Agassiz. On the Young Stages of some Osseous Fishes. I. Development of the Tail. Proc. Am. Acad., XIII., 1877, p. 117.

† A. Agassiz. Development of the Flounders. Proc. Am. Acad., XIV., 1878, p. 1.

‡ A. Agassiz. On the Young Stages of some Osseous Fishes. III. Proc. Am. Acad., XVII., 1882, p. 271.

§ A. Agassiz and C. O. Whitman. On the Development of some Pelagic Fish Eggs. Preliminary Notice. Proc. Am. Acad., XX., 1884, p. 23.

|| The following papers treating of fish eggs are referred to in this memoir: —

Malm, A. W. Svenska Vetensk. Akad. Handl., VII., 1867 and 1868.
Sars, G. O. Indberetninger til Departmentel for det Indre. Christiania, 1869.
Haeckel, E. Die Gastrula u. die Eifurchung. Jena. Zeits., IX., 1875.
Van Beneden, E. Quart. Journ. Mic. Sci., 1878, p. 41.
Kupffer, C. Archiv f. Mikr. Anat., 1868, p. 209.
Ryder, J. A. Bull. U. S. Fish. Com., I., p. 136, 1881.
Agassiz, A. Proc. Am. Acad., XIV., 1878, p. 1; XVII., 1882, p. 27.
Emery, C. Fierasfer. Arbeit aus d. Zool. Station zu Neapel.
Kingsley, J. S., and H. W. Conn. Mem. Boston Soc. of Nat. Hist., III., No. VI., 1883.
Hensen, V. Bericht der Com. zur wiss. Untersuch. d. Deutschen Meere, IV. Kiel, 1883.
Brook, Geo. Linn. Soc. Journal, XVIII., 1884, p. 274; XVIII., 1885, p. 299.
" " Quart. Journ. Mic. Sci., 1885.
McIntosh. Nature, XXXI., No. 806, p. 534, and No. 807, p. 555, 1885.

The first part of the present memoir is devoted to descriptive sketches of the different fish eggs which have come to our notice. We have, as far as practicable, given the most characteristic stages of the egg of each species, and have, whenever possible, raised the young until we could recognize in the embryo the young stage of some fish already known to us from our pelagic fishing. Many of the sketches here given of young fishes supplement those formerly published by Mr. Agassiz, and we have added a synoptic table of the various eggs and young fishes we have thus far observed, with references to the plates where they are figured. The difficulties of connecting the eggs and the free-swimming embryos is very great, and undoubtedly it will be found in the future, as we have already observed, that many of our identifications are not correct. The differences which distinguish the eggs of widely separated species are often very slight, and we found also that the variation in the size and ornamentation of the embryo was frequently very considerable. In fact, individual differences are early developed, and the peculiarities of the full-grown fish are hinted at most plainly either in the egg or in the very youngest embryonic stages after hatching.

A comparison of successive stages of growth (but not of the same individuals) of such young fishes as we figure in Plates III., XIII., XIV., XV., XVI., and XIX. will illustrate this point more fully than detailed descriptions of the different outlines and patterns of coloration of the successive stages.

We have also for one species (Ctenolabrus) illustrated quite at length (Pls. VII., IX.) the different stages of segmentation and the general appearance of the embryo within the egg before hatching.

The second part of this memoir will be devoted to the earlier stages of cleavage and the formation of the embryonic ring; after this we shall take up as fast as practicable the formation of the embryo, the fins, the chromatophores, the nervous system, and the alimentary canal.

The pelagic eggs we have had occasion to examine divide themselves into two great divisions, — those which are provided with one or more oil-globules, and those which are not. This distinction at first sight appears a most important one; yet if we examine eggs without globules, we shall find that the yolk-mass is thoroughly permeated with minute fatty globules. But these minute globules never coalesce, and do not form a number of small globules, as is the case in some of the Cottoids (Pl. I. figs. 1–3). We may indeed consider these eggs with many globules as intermediate between

eggs in which there are no large globules, no concentration of the fatty masses, as in Ctenolabrus and the like (Pls. VII., VIII., IX.), and those in which we find one or two globules. The fact that in the Cottoids we see the gradual concentration of these fatty masses to a smaller number of large globules as the egg advances in age, and furthermore the coalescence of two globules into one, would lead us to consider as of little importance this distinction of eggs based upon the presence or absence of globules. The oil-globule is often retained in quite advanced embryos.

We next find pelagic eggs which are laid singly, — that seems to be the most common condition, — and are left to float at the mercy of the winds and waves. Other eggs, on the contrary, are laid in a common connecting glutinous mass, like those of Lophius, Fierasfer, and others. In the former genus the mass of eggs is very large; in the latter, the number of eggs is quite small. As far as protection to the young embryo is concerned, the eggs which are laid singly and are soon scattered far and wide would seem to be in the best condition to escape their numerous enemies, while the large masses of pelagic eggs, or those which are laid attached to the bottom in clusters, would seem completely at the mercy of other Fishes, and of Crustacea, Mollusca, Annelids, and other marine animals living upon animal food.

All the eggs described in this memoir, — those without oil-globules as well as those with them, — except when confined in masses, usually float with the embryo down. Pelagic eggs are usually, as far as we have observed them, perfectly transparent when first laid; little by little, with the formation of the embryo, chromatophores are formed, generally upon the surface of the yolk-mass close to the embryo, or upon the embryo itself. These chromatophores, at first colorless, then become pigmented, and while the young embryo is still within the egg the characteristic pattern of coloration is often clearly indicated. They extend gradually over the whole embryo, which, before the tail is well advanced, is usually completely covered by characteristic pigment; it is only with the growth of the tail that the individual characteristics of coloration are plainly visible. (See the eggs of Plates II., VII., X., XII., XIV., XVI.–XIX.)

The yolk-mass, which in the earlier stages of the egg fills nearly the whole outer envelope, is gradually resorbed with the formation of the embryo. This resorption is very different in different species, and upon it depends, of course, the size of the yolk-mass at the time the young fish is hatched. (Compare Pl. II. fig. 3, Pl. III. figs. 8, 9, Pl. X. figs. 4, 6, Pl. XI.

figs. 8, 10, Pl. XII. figs. 6, 7, Pl. XIII. figs. 10, 11, Pl. XIV. figs. 6, 7, Pl. XVI. figs. 6, 7, Pl. XVII. fig. 6, Pl. XVIII. figs. 6–9, Pl. XIX. figs. 4–6.)

The speed of the resorption of the yolk mass varies also greatly, as can be readily seen while comparing the young embryos of the stages indicated above. The rapidity of development of the structural features of the young fish is correlated with the decrease of the size of the yolk-bag. We find in those young fishes, for instance, in which the yolk-mass retains for many days an inordinate size, that the development of the head, the fins, the eyes, and the pigment-spots has been comparatively slow.

It is rather an unusual thing to find the chromatophores dendritic in the earlier stages within the egg, although in a few species in which the pigment is principally black this seems to be the case. (Pl. II. fig. 2, Pl. XIII. fig. 3, Pl. XVII. fig. 1, Pl. XVIII. figs. 4, 5.)

Soon after hatching, however, the development of the dendritic pigments is very marked; the black pigments are usually the first to be extended, and the colored chromatophores appear in later stages, except in those species (as in some of the Cottoids) in which the colored chromatophores form the basis of the ornamentation even in the earliest stages. The arrangement of the patterns of coloration is also blocked out soon after hatching, during the earliest stages of growth. (Pl. II. fig. 12, Pl. III. figs. 9–11, Pl. V., Pl. XIII. fig. 15, Pl. XV.)

The eyes are generally colorless until some time after the hatching of the embryo, but in some species the chromatophores extend over the eye (Pl. II. figs. 6, 7), and in others (Pl. II. fig. 2, Pl. XII. fig. 3, Pl. XVIII. fig. 5) there is an accumulation of black granules in the posterior part of the eye while still within the egg. Ordinarily the eye does not become pigmented black till after hatching, and the coloring is not developed until somewhat later stages. (Pl. XI. fig. 11, Pl. XIII. figs. 14, 15, Pl. XV., Pl. XVI. figs. 8, 10, Pl. XVIII. fig. 10, Pl. XIX. fig. 7.)

The first fins formed are the pectorals, traces of which appear in very early stages within the egg (Pl. XII. fig. 1, Pl. XIV. fig. 2, Pl. XVI. fig. 2, Pl. XVIII. fig. 2) as slight swellings in the sides of the body of the embryo. The closing of the blastopore and the disappearance of Kupffer's vesicle are followed by the growth of the tail (Pl. II. fig. 4, Pl. X. fig. 1, Pl. XII. fig. 1) and the formation of an embryonic tail-fin, which increases in width with the increase in size of the posterior part of the body (Pl. II. figs. 6, 8, Pl. XII. figs. 2, 3, Pl. XIV. figs. 3–5, Pl. XVI. figs. 3, 4, Pl. XVIII. figs. 3–5, Pl. XIX.

and form either fins or tactile appendages intended for special functions, as in Motella and Lophius among our shore fishes, and among many of the deep-sea fishes, where in addition the comparatively simple lateral organs become greatly developed into special sense appendages.

From the embryonic fin-folds, by resorption and development of special parts, are formed the caudal, the dorsals, and the anal, the ventrals are developed from the rudimentary embryonic fin fold extending from the vent toward the head along the lower side of the yolk-mass.

The caudal is usually the first fin to become specialized from the embryonic fin-fold, though in some cases the ventrals are developed first. The formation of the dorsals and anal goes on *pari passu*; the posterior dorsal, however, is developed usually before the anterior dorsal, when the fins are similar; but when, as in the case of Lophius and Cyclopterus, they form (as well as the ventrals) special organs, as it were, their rudiments are early to appear. The fin-rays of the pectorals make their appearance first; next come those of the caudals; the dorsal and anal fin-rays are synchronously developed. The delicate embryonic fin-rays of the primitive fin-fold are first formed at the caudal extremity, then gradually extend over the whole of the embryonic fold. The base of the definite fin-rays is the first to appear, and in the early stages these folds are completely covered by a more or less coarse granulation, which also covers the yolk-mass. Mr. Agassiz* has already alluded to the crossopterygian character of the embryonic pectorals of the young of osseous fishes.

The comparatively large size of the chorda in the earlier embryonic stages is a marked feature of all young fishes. On leaving the egg, the sheath is surrounded by a thin muscular belt, which increases in thickness with the age of the fish. The diagonal muscular bands make their appearance early in the embryo, while still in the egg. They are at first most distinctly marked toward the median part, diminishing in distinctness as they extend toward the head, and gradually reaching toward the extremity of the tail. With increasing age the large cells of the chorda become subdivided into smaller ones, and finally assume a granular appearance at the time when the subdivisions of the vertebral column and the first trace of the apophyses appear.

We have been greatly struck, while making these investigations, by the regularity with which the same stages of development of identical species

* A. Agassiz. Proc. Am. Acad., XVII., 1882, p. 297, Pl. XIX. figs. 4–6.

figs. 2, 3), and at the time of hatching extends as a median vertical fold along the whole dorsal line, returning on the ventral side as far as to the yolk-sac. (Pl. II. fig. 3, Pl. III. fig. 8, Pl. X. fig. 4, Pl. XI. fig. 8, Pl. XII. figs. 6, 7, Pl. XIII. figs. 11, 12, Pl. XIV. figs. 6, 7, Pl. XVI. figs. 7, 8, Pl. XVIII. fig. 6, Pl. XIX. figs. 4, 5.)

With the resorption of the yolk-mass is connected the disappearance of the embryonic fin fold in advance of the vent, and usually at that time (Pl. II. fig. 12, Pl. III. figs. 10, 11, Pl. XIII. figs. 14, 15, Pl. XV. figs. 13, 14) the pectorals are well developed and have become a powerful limb in the young embryo. The resorption of the yolk-mass is also accompanied by a lengthening of the intestinal tract, and the formation of a larger alimentary canal and of a swimming-bladder. (Pl. II. fig. 12, Pl. XI. figs. 11, 12, Pl. XIII. figs. 13–15, Pl. XV., Pl. XVI. figs. 8–10.) In some cases (Pl. II. fig. 3, Pl. XII. figs. 6, 7, Pl. XIII. figs. 11–14, Pl. XVII. fig. 2, Pl. XVIII. fig. 6), where the vent when the young fish is hatched is not marginal, but lateral, this gradually moves down toward the edge of the embryonic anal fin. In the very youngest stages, immediately on leaving the egg, the embryo depends mainly upon its embryonic dorsal and ventral (its leptocardial fin) for locomotion. The propelling powers of this fin are proportionally very large, and at no time of its life is the young fish better provided with means of locomotion, or with organs of sense to detect the most minute changes in the medium surrounding it. Compare, for instance, the muscular axis of a newly hatched embryo (Pl. II. fig. 3, Pl. X. fig. 4, Pl. XII. figs. 6–8, Pl. XIII. fig. 12, Pl. XVI. fig. 6, etc.), the size of the embryonic fin, the comparatively great bulk of the brain and of the chorda, the immense size of the eyes, the great development of the lateral organs, and the size of the auditory capsules, with those of a more advanced embryo (Pl. XI. fig. 12, Pl. XV. fig. 14), and then with the older adult stages of these same fishes, and we cannot fail to be struck by the contrast they present. Everything in the young embryo seems eminently adapted to enable it to receive the most delicate impressions, whether it be from its exquisitely sensitive lateral line or from its huge eyes; and its gigantic embryonic fins enable it with comparative ease to move rapidly away from disturbing influences, to say nothing of their extreme transparency and their power of reducing the pigments which cover them to a minimum while in rapid motion, and thus readily to escape from their enemies.

With the growth of the embryo the young fish depends more and more for locomotion upon the use of its pectorals, and these develop quite rapidly,

have appeared in successive years. In fact, whenever we were particularly anxious to find a given stage, the date of occurrence of former years formed an infallible guide in our search. This regularity in the appearance of pelagic animals is not limited to young fishes, but we find that the time of spawning of the majority of marine animals and their rate of development are practically identical year after year. We may quote as instances the appearance of Plagusia, Agalma, Arachnactis, Balanoglossus, and hosts of other embryos, on fixed days, as examples of the close interdependence we find between the season and the temperature of the sea with the growth of pelagic life.

Cottus grœnlandicus, C. & V.

Cf. Agassiz's Young Fishes, Part III., Pl. III. and Pl. II. Figs. 1 and 2.

Plate I. Figs. 1–5.

The eggs referred to this species are found throughout the summer months, but are most abundant in July. They are easily distinguished with the naked eye by their large size (1 to 1.1 mm.), and especially by the presence of scattered oil-globules, the number of which in a single egg may vary between ten and forty. These oil-globules are sometimes distributed more or less evenly in the periphery of the yolk (Figs. 1 and 3), and sometimes a tendency to cluster is shown by some or all of them (Fig. 2). In size they vary from .02 mm. to .10 mm. No instance of coalescence into a single globule has been noticed. Their peripheral position shows that their place in the yolk is not determined by specific gravity alone.

Yellow pigment begins to appear in this species three or four hours before the closing of the blastopore, about the time the first somite becomes plainly marked off, and almost simultaneously with the minute cluster of vesicles which are destined to coalesce, and thus give rise to Kupffer's vesicle. The pigment is at first extremely pale, and confined to a few mesoblastic cells along each side of the embryo. In the course of an hour the number of yellow pigment-cells is much increased, and a few black pigment-dots make their appearance. By this time some of the pigment-cells of both colors have wandered away from the lateral mesoblastic masses of the embryo, and appear as isolated amœboid cells between the ectoderm and the layer which we have called the periblast.

Thus far not a single pigment-cell has appeared anywhere in front of

the posterior margins of the optic vesicles. The yellow pigment is densest along the two sides of the embryo; and between these two lines, on the dorsal surface, only a few chromatophores are to be seen, and these are all black. At the end of another hour we find the pigment-cells more numerous, and two or three yellow cells are now to be seen on the optic vesicles. The black pigment-dots are smaller than the yellow ones, and mainly confined to the dorsal surface of the embryo. The yellow pigment-dots are both larger and darker than in the preceding stages, appearing bright yellow by reflected light, and brownish yellow or orange by transmitted light. At the time of closure of the blastopore, from three to four hours after the first appearance of pigment, the brownish yellow chromatophores are still larger (.005 to .008 mm.), and have crowded into the constrictions which separate the optic vesicles from the brain. A few of these cells are now seen among the black cells on the dorsal surface. Soon after this stage pigment-cells are found scattered over the entire surface of the yolk (Figs. 1 and 3).

At the time of hatching (see Agassiz, *loc. cit.*, Pl. III. figs. 2, 3) there are generally two large patches of brownish yellow along the margin of the dorsal fold, and four along the ventral. The outer edge of the pectorals is colored in the same manner. Two varieties are seen (in Figs. 4 and 5), which differ so widely from the typical form described by Agassiz as to raise the question whether they do not represent a second, and perhaps a third species.

The specimen represented in Fig. 4 was hatched from an egg measuring only .85 mm., and having 25 oil-globules. Another egg of nearly the same size (.82 mm.) was obtained at the same time, and this had only 8 oil-globules. The bright orange pigment-cells were very numerous on the dorsal and ventral folds, as well as the body, except at the caudal end, where only a single black cell was seen. Some black dots were scattered over the middle third of the body and on the yolk-sac alongside the embryo. The surface of the embryo was very rough or granular.

In Fig. 5 three patches of pigment are seen on the embryonic fold. The chromatophores of the body are still in a state of contraction. They are much less numerous, and their distribution much more even, than in Fig. 4. This specimen was hatched from an egg measuring 1.10 mm. in diameter, and having a very opaque zona radiata, which presented a blotched appearance when examined under a magnifying power of a few hundred diameters. The dimensions of Fig. 4 are as follows: —

Length	2.00 mm.
Yolk-sac (ovoid)	.80 × .47 "
Yolk-sac to vent	.10 "
Vent to tip	.95 "
Width of head	.30 "

Dimensions of Fig. 5 : —

Length	3.00 mm.
Yolk-sac	.60 "
Yolk-sac to vent	.20 "
Vent to tip	1.90 "

Species No. 28.

Plate I. Figs. 6–8.

Our knowledge of this species is limited to what could be learned from a single egg, found August 15, 1884.* This is the smallest of the eggs described in this paper, measuring only .63 mm. by .65 mm. The oil-globule is also diminutive in size, being only .085 mm. in diameter.

Shortly after the closure of the blastopore (Fig. 6) the yolk and embryo are very transparent, the only pigment being a few small, round black dots (about .005 mm.) scattered over the dorsal surface of the embryo and the yolk-sac in the neighborhood of the globule.

Thirty hours later, at the time of hatching, the pigment consists of scattered black dots, yellow dots, and four round black spots, placed as shown in Fig. 7. A few black and yellow dots are seen on the oil-globule, but none on the yolk.

Dimensions taken from Fig. 7 : —

Length	2.10 mm.
Yolk-sac	.70 × .35 "
Yolk-sac to vent	.05 "
Vent to tip	1.20 "
Height	.45 "
Width of head	.225 "

The specimen represented in Fig. 8 was taken in September, 1883, and is probably a somewhat older stage than that of Fig. 7. The lateral position of the vent makes it quite certain that this specimen, if normally developed, does not belong to the same species. In other respects, however, there is a close resemblance, allowing for the fact that the yellow pigment is expanded in Fig. 8 and contracted in Fig. 7.

* The egg and young of this species have also been taken this season (July 6, 1885) by Mr. Agassiz.

Species No. 26.

Plate II. Figs. 1–3.

Two eggs only of this species (Motella, or some closely allied fish) were obtained during the summer of 1884, and these were taken on July 25. The stages represented in Figs. 1 and 2 resemble somewhat the corresponding stages of *Motella argentea*, seen in Pl. XVIII. figs. 3 and 5; but differ from them in having less pigment, a colored globule, and a more granular aspect, which is most strongly developed on the yolk around the head. These eggs measured respectively .75 mm. and .76 mm.; and the brassy yellow oil-globule in each was .14 mm. in diameter.

In one egg there was no pigment on the yolk, and in the other (Fig. 1), only a single small spot near the embryo. In the younger stage (Fig. 1) the embryo is already remarkably granular, the granules being larger on the yolk at either side of the head than elsewhere. In the stage of Fig. 2, just before hatching, the granulation is somewhat stronger, and the inner and posterior part of the eyes is marked with black dots. The pectorals are well advanced, and there is a manifest concentration of pigment in definite regions, which foreshadows the condition reached a few hours after hatching. In the stage of Fig. 3, twelve to eighteen hours old, the pigment is arranged almost precisely as in the young Motella (Pl. XVIII. fig. 6), but is much less richly developed. The eye is blue-black, with a reflection of yellow. The lateral line organs agree both in position and number with those of the allied, but plainly different, species figured in Plate XII. In size, general shape, position of the vent, and dimensions, this species agrees closely with the two species above referred to.

Hemitripterus americanus, C. & V. (H. acadianus, Storer.)

Plates II. and III. Figs. 4–12.

The eggs here described and referred to Hemitripterus are characterized by a rich development of pigment, which makes its appearance some time before the closure of the blastopore. The egg is comparatively large (1.02 to 1.10 mm.), and has a single oil-globule (.15 to .16 mm.), by which it is easily distinguished from the Cottus egg, with which it agrees in respect to the early and copious development of pigment. By the time the tail becomes well rounded (Fig. 4) we find the embryo thickly pigmented

from end to end, and a few chromatophores on the yolk alongside the embryo.

As in the Cottus embryo, there are two kinds of pigment-cells, — the brownish yellow (lemon-yellow by reflected light) and the black. The yellow cells, which are by far the more numerous, are generally round, and thickest along the sides of the embryo. The black cells are smaller, more or less angular, and mainly confined to the median dorsal surface of the embryo. Both kinds of pigment are seen on the oil-globule; but here the yellow cells are confined to the external half of the globule, while the black cells are restricted to the opposite (inner) hemisphere.

A little later (Fig. 6) we find the entire yolk covered with the two kinds of pigment-cells, many of which are expanding, as shown by their irregular form and pseudopodial prolongations. This expansion is carried still further in the next stage (Fig. 7, just before hatching), where we find patches of diffuse brownish yellow resulting from the confluence of expanded chromatophores.

At the time of hatching (Fig. 8) the condition of the pigment on the body and yolk-sac is about the same as in the stage of Fig. 7, with the exception that the yellow pigment stops short some distance in front of the tip, while the minute round black dots may be traced to the very end of the muscular axis. At this time three large pigment patches are found on the embryonic fold, two on the dorsal portion, and one on the ventral, as shown in Figs. 8 and 9. These patches are usually elongated in a longitudinal direction, and placed about midway between the margin of the fold and its base. They consist mainly of yellow chromatophores, with a few black cells intermingled. A few chromatophores actually contain black pigment granules mixed with the yellow. This union of two different pigments in the same cell has been noticed in other cases. The color of the young fish varies much from moment to moment, according to the contraction or expansion of the chromatophores. Cells with a brownish or reddish hue when contracted, often appear bright yellow when distended. There can be but little doubt that those young fishes which exhibit such rapid and conspicuous variations in color have what has been called the "chromatic function." The protective nature of these color changes, which have been so well described by Heincke in the case of *Gobius Ruthensparri*, is very evident in the young Tautog and Cunner, and still more so in young Flounders.*

* A. Agassiz, Young Stages, Part II. pp. 3, 11, 14–18; Emery, R. Acad. d. Lincei, 1882–83 (Blennius).

There is considerable variation in the width of the embryonic fin fold of this stage; and the differences in this respect, seen in Figs. 8 and 9, is not to be accounted for by the difference in age. The arching of the dorsal fold at the time of hatching is not often so pronounced as in Fig. 8, and is frequently less than in Fig. 9, which represents a stage of thirty-six hours. The round, fleshy pectorals are now quite prominent. The yolk-sac is very large, and broadly ovate in form. The dimensions of this stage are as follows: —

Length	2.70 mm.
Yolk-sac	.92 × .65 "
Yolk-sac to vent	.15 "
Vent to tip	1.50 "
Width of head	.40 "
Width of body (at level of vent)	.17 "

The three remaining stages (Figs. 10–12) were captured by surface skimming, and their age is therefore unknown. The principal changes consist in the disappearance of the yolk-sac, the prolongation of the snout, with the lower jaw far in advance of the upper, the appearance of two thickenings in the embryonic fold for the dorsal fins, the diminished breadth of the fold, especially in the posterior half, the presence of large pectorals, bluish green pigment in the eyes, and the more highly developed state of the black chromatophores, now represented by numerous radiating dendritic cells scattered over the sides.

The eggs of this species are found through the summer months, but never in very large numbers.

THE BLUE-FISH.

Temnodon saltator, Lin. (**Pomatomus saltatrix,** Gill.)

Plates IV. and V. Figs. 1–15.

Nothing definite is known in regard to the breeding habits of the Blue-fish, and no description of the eggs has been given. The egg here figured is easily distinguished from other pelagic fish eggs by the partial segmentation of the yolk; and it is quite probable that an examination of ripe eggs obtained from the fish would clear up the uncertainty in respect to the species to which it belongs. We have found these eggs from the middle of June to the middle of August, but never more than a few at a time. It is most abundant about the middle and latter part of July. As a rule, the egg

does not vary much from .70 to .75 mm. in diameter, but we have recorded instances which show a remarkably wide range of variation in size, the maximum and minimum limits being represented by .84 mm. and .66 mm. The oil-globule usually measures from .18 to .19 mm., but may vary between .17 mm. and .23 mm.

It is rather remarkable that we have never obtained stages much younger than that given in Figs. 1 and 2, although we have collected in all parts of Newport Bay, and at all times of the day. It is probable that the eggs are laid at some distance outside the Bay, which would account for the absence of earlier stages, as well as for the small number of eggs obtained at a time.

The egg agrees very nearly in size with our No. 15, but the peculiar segmentation of the yolk makes it quite impossible to confound the two eggs. In our Preliminary Report * we were probably mistaken in regarding the segmentation of the yolk as an evidence of cleavage. The segments perfectly resemble cleavage-spheres, and often appear to be nucleated. But sections of a large number of these eggs, in different stages of development and after different methods of preservation, have failed to give any satisfactory evidence of nuclei. What appeared to be nuclei in the living egg turn out to be superficial masses of protoplasm, which are usually located beneath nuclei belonging to the periblastic layer. These masses stain deeply, but vary too much in size to be nuclei, and in other respects show plainly that they cannot be identified with nuclear bodies. Before examining sections, it seemed not improbable that these yolk-segments either represented the periblast or played some important part in its production. But we have not obtained any evidence in favor of either view. The youngest stage that has been obtained was taken in June of this year (1885). In this egg the wreath of periblastic cells had just appeared. These cells were more clearly and perfectly outlined than in any other egg we have studied, but they lay above the yolk-segments and appeared to owe their origin to the marginal cells of the blastoderm, precisely as in other teleostean ova. In sections of eggs in the stage represented in Fig. 1, the periblastic cells already have a syncitial character and form a layer in all respects like that we have before described in other eggs. The stages we have obtained give no clue to the origin of the yolk-segments. They are well defined, and their outlines remain clear in most of our preparations. Their nature and mode of origin can only be ascertained by a study of earlier stages, and perhaps a study of the ovarian

* Agassiz and Whitman, Proc. Am. Acad. Arts and Sci., XX. p. 31.

egg will be required. One or two facts are worthy of note in the subsequent history of these yolk-segments. They have an epibolic growth, gradually expanding around the unsegmented yolk as this becomes enclosed by the blastoderm and periblast. During this expansion it becomes evident that the segments are not only diminishing in thickness, owing to an increased surface extension, but also in absolute bulk, as may be seen by comparing Figs. 3 and 6. They are visible at the time of hatching (Fig. 7), and for a short time afterward. This decrease in bulk, taken in connection with the nucleus-like aggregations of protoplasm seen on the outer periblastic surface of the segments, suggests that the substance of these segments is gradually appropriated by the periblast. In the movement of these yolk-segments from one pole of the egg to the opposite side, we have ocular evidence that the epibolic growth of the blastoderm is accompanied by a transposition among the yolk-elements, closely analogous to the invaginatory movement of the yolk in holoblastic ova. It is highly probable that this sort of solid invagination is the mechanical result of the peripheral expansion of the blastoderm, and that it is not an exceptional feature in the development of telolecithal vertebrate ova, but a general one. In the second part of this work this point will receive further consideration.

Pigment makes its appearance soon after the closing of the blastopore. It is confined to the embryo and the oil-globule, and consists of round black dots, from .005 mm. to .01 mm. in diameter, placed along the dorsal angles of the muscle-plates. Viewed from above, these dots form two rather irregular lateral lines, reaching from just behind the head to near the end of the body. In a profile view the dots are scattered over the whole dorsal surface of the anterior half of the body, but they are more numerous along the two lateral lines. The whole yolk is now enclosed by the large yolk-segments, with the exception of a broad zone along each side of the embryo. It should be remembered that the area first occupied by the yolk-segments corresponds, in part at least, with that now held by the embryo; it is evident from this that these segments have shifted their position from the dorsal to the ventral side, and in so doing have become separated along a median dorsal zone.

Shortly before hatching (Fig. 6) we find a considerable number of brownish yellow chromatophores intermingled with the black in the first two thirds of the body; in the tail, the pigment-cells are few in number, small, and all black. At the time of hatching (Fig. 7), — about thirty-six hours after the

closing of the blastopore, — the chromatophores are usually larger than in the stage of Fig. 6, but less numerous. Up to this time no pigment appears on any part of the yolk except around the oil-globule. The brownish yellow pigment consists of rounded or branching cells scattered along the body from the head to a point just behind the vent. The black cells reach farther back, and are all placed at the dorsal angles of the myotomes. In nearly all the black cells of this stage one or two brownish yellow granules (.01 mm.) may be seen. By this time most of the black chromatophores have taken an angular or coarsely branched form.

The measurements of this stage are as follows: —

Total length,	2.15 mm.
Yolk-sac,	.75 × .40 "
Yolk-sac to vent,	.275 "
Vent to tip,	1.00 "
Width of head,	.275 "
Height at anterior end of yolk-sac,	.575 "
Height at posterior " "	.50 "

Yellow pigment-spots appear along the edge of the dorsal fold in the next stage (Fig. 8); but these become smaller by the fourth day (Fig. 10), and wholly disappear between the fifth and ninth days. In all the remaining stages of Plate IV., and up to the fifth day, the black pigment undergoes very little change. The yellow pigment reaches its highest development in the course of the first two or three days, and never extends much beyond the anterior half of the fish. From the ninth day onward (Fig. 11 and the following) it takes a diffuse form, and becomes less and less prominent until it finally disappears. In the earlier stages here figured, the dorsal fold is well arched, and its height and proportions scarcely undergo any notable changes during the first nine days. Between the fifth and ninth days the eye assumes the blue color seen in all the subsequent stages. The upper side of the eye alone is black.

In the stage seen in Fig. 12 we find a dorsal and ventral row of black chromatophores in the posterior half of the body, which mark the region of thickening for the dorsal and anal. At the bases of the hypaxial rays of the caudal lobes are to be seen four or five spots, which may be regarded as a continuation of the ventral row. There is a concentration of black pigment along the intestinal tract, another in the upper part of the eye, and a third on the hind part of the head. In the remaining stages the pigment becomes more strongly developed in these different regions, and in the last stage the

whole dorsal line of the body is marked by a dense line of black pigment. In Fig. 12 a small patch of blue is seen below the pectoral, and this becomes much larger in subsequent stages. In passing from Fig. 11 to Fig. 15, we have a very complete series, exhibiting all the principal transitional phases of the tail, from the leptocardial (= *protocercal*, Wyman, *lophocercal*, Ryder) to the homocercal condition. The serial homology of the permanent caudal with the anal is well shown in Fig. 14. The obvious functional importance of the caudal has both strengthened and accelerated its development, and at the same time may contribute to bring about the upward curvature of the caudal axis, as maintained by Ryder.*

Fig. 15 represents a small Blue-fish, measuring 9 mm. in length. The tail fin is but slightly forked; the anterior dorsal is rudimentary, but the base of the permanent fin-rays is already present; permanent fin-rays are present in the posterior dorsal, as well as the anal; the pectorals are large, and the ventrals rudimentary. The teeth of the upper and lower jaws are already quite prominent. The eye is bright blue, and the body bluish silvery with a few faint pigment-cells uniformly scattered over the flanks. The Carangidæ with rudimentary ventrals and no anterior dorsals are evidently genera representing the embryonic stages of this family.

Already when quite young the Blue-fish shows its ferocious habits. Small fishes of the size of those figured in Plate V. (Fig. 12) attack other young fishes if kept in the same glass dishes. By the time the little Blue-fish have reached the size of Figs. 14 and 15 in Plate V., they are fully as dangerous to other fishes as are the merciless adults while in pursuit of their food. A couple of young of these dimensions will attack much larger Flounders, Motellæ, Cunners, or Smelts, and soon devour every living thing kept in confinement with them for any length of time.

Lophius piscatorius, Lin.

Plate VI. Figs. 1–10.

The eggs of Lophius have been obtained early in June and late in August. They are laid in an immense mucous band, from two to three feet broad and from twenty-five to thirty feet or more long. Occasionally a single egg is found floating at the surface. The mucous mass is of a light

* John A. Ryder. "An Outline of the Development of the Unpaired Fins of Fishes," American Naturalist, 1885, p. 94.

violet-gray color; but, owing to the great development of black pigment in the embryo, the band has a somewhat blackish appearance. The eggs are arranged in a single irregular layer, and each is enclosed in a gelatinous envelope which has about twice the diameter of the egg, and which thus gives space enough for it to move freely. The envelopes are thin and membrane-like, and glued together by a homogeneous layer of mucous (Figs. 1 and 2). Pressure causes the envelope to wrinkle, showing that it is really membranous in character, although it may be only a modified layer of the mucous mass.

The egg is very large, measuring 1.75 mm. in diameter, and has a single immense oil-globule (.40 to .42 mm. in diameter) of a beautiful transparent copper-color (Fig. 1). The yolk is transparent, like that of all the pelagic fish eggs we have described. In the youngest stage which we have obtained (Fig. 1) there is already a dense veil of black dendritic cells on the ventral side of the embryo, which obscures its outlines. The pigment extends over the dorsal surface also, so that the embryo appears to the naked eye as a black streak across the egg. The pigment increases rapidly, and a little later we find the eyes perfectly black (Fig. 4) and the oil-globule enveloped in a thick network of these cells. The pigment spreads to other parts of the yolk, but is mainly concentrated on the dorsal side beneath the embryo. Fig. 9 gives a good idea of the appearance of the pigment shortly before hatching.

At the time of hatching, the yolk-sac is quite globular, but much reduced in size. In this stage the young fish bears little resemblance to the adult form. It has only a single (first) dorsal appendage, a narrow, short spatulate ventral, and a small circular pectoral. (See Agassiz, *loc. cit.*, Pl. XVI. Fig. 4.) In this stage, as well as while still in the egg, and until it is far more advanced, the embryo is remarkable for the great width of the embryonic fold, the straight notochord, and the three or four prominent patches of intense black pigment placed at equal intervals along the lower, upper, and terminal parts of the chorda. The tail pigment-spots extend on both sides of the chorda, and form the largest of the three patches. This is the case from the earliest stages, until the body of the young Lophius is completely covered with pigment. In the earlier stages the embryonic fold is covered with minute, round black pigment-spots. It is only in much more advanced stages that we begin to find traces of the ordinary dendritic spots which eventually cover the dorsal, anal, and caudal fins.

The young Lophius is very active during its embryonic stages, in striking contrast to the sluggish habits of the adult. The adult is, comparatively speaking, a deep-water fish. It was dredged by Agassiz in the "Blake," as low down as 320 fathoms, off Newport. The females undoubtedly come to more shallow waters to spawn, as they are not an uncommon fish along the shores during June, July, and August, being frequently found left by the tide on the flats where they come to spawn. The young fishes frequently assume, when at rest, an inclined position, much as the young Garpike, and do not float horizontally as other bony fishes do.

Somewhat similar to the egg-ribbons of Lophius are the masses of eggs laid by Fierasfer, described by Risso and Cavolini, and also well figured by Emery, who has followed the development of the young, and given excellent figures of different stages. (See Emery, Pl. I. Fig. 2, and Pl. II. Figs. 5–7.) Like the young of Lophius, they assume also a peculiar slanting attitude, characteristic of certain stages of growth. It is remarkable that such distant types as Lophius and Fierasfer should in their embryonic stages show such close resemblances. The temporary dorsal appendage, which is so prominent in the young Fierasfer, is developed much in the same way as the permanent dorsal appendages of Lophius, which are eventually changed to the appendages used for fishing by the adult. What part this temporary dorsal appendage plays in Fierasfer is not known; but Emery supposes it to have the same function as in Lophius.

Ctenolabrus adspersus, Walb. (**C. cœruleus,** Storer.)

Plates VII., VIII., IX. Figs. 1–34.

The spawning season of Ctenolabrus begins as early as the middle of May (possibly earlier), and extends to about the first of July. The eggs are most abundant during the last week of May and the first two weeks of June. After the first of July very few Cunners are found with gravid ovaries. The eggs of *Pleuronectes americanus*, which resemble closely those of the Cunner, and which were always confounded with them until the summer of 1884, are quite abundant in July, and are found until late in August. This accounts for the statement made in Agassiz's Young Stages of Osseous Fishes (Part III. p. 290), that the eggs of the Cunner are found during the whole summer. This confusion will hardly appear surprising in view of the fact that we are unable even now to point out a single distinctive fea-

ture which could serve as a reliable means of identifying the two kinds of eggs prior to the time of hatching. The eggs of the Cunner are, on the average, a few hundredths of a millimeter larger than those of the Flounder (*P. americanus*), but this distinction is fully bridged over by variations on both sides. Although the periods of occurrence are consecutive, they overlap each other, and hence do not afford even an indirect means of identification. The character of the pigment, its time of appearance, and its development appear to be the same in both kinds of eggs. At the time of hatching there is a very constant difference in the size and shape of the yolk-sac, that of Ctenolabrus being comparatively large and ovate in form, while that of the Flounder is proportionally smaller, and oblong-elliptical in shape. The Flounder is longer and more slender at the time it leaves the egg-membrane than the Cunner of a corresponding age.

For embryological study, the eggs of the Cunner offer special advantages in the way of easy and abundant supply of material; for they are obtainable at all hours of the day, either directly from the sea or by artificial fertilization. Most of our material for the study of the early stages has been derived from this source; and as the teleostean type of development is well exemplified in these eggs, we have given in Plates VII. to IX. a selection of the principal stages, forming an outline sketch up to the time of hatching, reserving a more detailed account for the second and third parts of this memoir.

The condition of the freshly laid egg, which measures from .85 to .92 mm. in diameter, is shown in Plate VII. fig. 1. The whole cortical layer of the egg, which is now everywhere of the same thickness, is densely filled with refractive granules, which render the egg quite opaque. A few moments after fecundation all or nearly all of these granules have dissolved, leaving the egg completely transparent. Immediately after the penetration of the spermatozoön a disc-like thickening of the cortical layer appears at the lower pole of the egg; and at the centre of this disc may be seen, in mounted preparations, the minute male pronucleus. It is a curious fact, of which the proof will be given in our second memoir, that the male pronucleus becomes the centre of attraction around which the discoidal aggregation of protoplasm takes place, and towards which, after the formation of the second polar globule, the female pronucleus gravitates. In the course of a few minutes the blastodisc becomes quite prominent, as shown in Figs. 2 and 3; and a few minutes later the first cleavage-furrow appears, dividing the disc into two nearly equal parts (Fig. 4). A second furrow at right angles

to, and a third parallel with the first, lead to the four-cell and eight-cell stages (Figs. 5, 6, 7). The sixteen-cell stage is reached by grooves running parallel with the second cleavage-plane, beginning as shown in Fig. 10, and ending by producing an oblong disc of cells arranged as in Figs. 8, 9, 11, 12. This form of the disc is often preserved through a considerable number of the succeeding stages, but sooner or later passes into the circular form of Figs. 14 to 18. The direction of the individual cleavage-planes becomes more and more difficult to follow in detail after the sixteen-cell stage is reached, and beyond the sixty-four-cell stage they can only be traced in a general way. In passing from the sixty-four-cell stage some of the inferior marginal cells become split off from the blastodisc, and by the time the stage of Fig. 18 is reached they cease to have any distinct boundaries, and we see only a wreath of nuclei around the edge of the disc. A few hours after the first appearance of this wreath of nuclei in the layer of protoplasm which we have designated as the periblast, the blastodisc enters upon a series of transformations, which culminate in the formation of the embryo. The most conspicuous part of these changes consists in an expansion of the blastodisc, accompanied in its first stage by an infolding or ingrowth of the marginal cells, which gives rise to the embryonic ring shown in Fig. 19. This ring is composed of two layers, — an upper (ectoderm) and a lower (entoderm and mesoderm); and from it, by a process of axial concentration, which is in principle a concrescent growth, the embryo is formed. The formation of the ring requires only a few minutes; and before it attains its full width, we notice that there is a more rapid growth at one point than elsewhere (Fig. 21). It is at this point that the axial concentration is taking place to form the embryo. The axial portion has a rapid centripetal growth, but also lengthens backward in proportion as the circumcrescent or epibolic growth of the blastoderm advances. The lengthening of the embryo, and the concomitant expansion of the blastodisc, which carry the embryonic ring over the yolk-sphere and end by bringing the halves of the ring completely together at the hind extremity, are shown in successive stages in Figs. 21 to 26. The nature of the processes by which the embryonic ring is gradually converted into a bilateral embryo will be considered in detail in the third part of this memoir, and hence the controversies on this point need not occupy us here. In the same place we shall consider the broad embryonic plate stretching out on either side of the embryo in Fig. 24, and its relations to the embryo. By the time the ring closes (Fig. 26), scarcely a trace of

this sheet of cells remains, the whole of it having been incorporated in the body of the embryo.

As in the Tautog, no trace of pigment appears in the egg until some time after the closing of the blastopore. They are first seen as minute black dots (.003 mm. in diameter) scattered along the middle third of the dorsal surface of the embryo. By the time the stage of Fig. 27 is reached, the dots are larger and somewhat more numerous, and extend in two more or less irregular lateral lines along nearly the whole length of the embryo, being absent only on the fore part of the head and the tip of the tail. From this stage to the time of hatching (Figs. 28–31), the pigment-cells increase somewhat in size, while remaining about the same in number. They still preserve the round form in the stage of Fig. 31, the larger ones measuring .01 mm. in diameter; and, roughly speaking, they appear to form two lateral lines when seen from above. In profile views, the dots are seen to be confined to the dorsal half of the body, precisely as in the case of the young Tautog. The embryo of this stage differs, however, from the Tautog and *Ps. melanogaster* in having no wreath of pigment around the head, and in the extension of the pigment to the very end of the muscular axis.

Measurements at the time of hatching: —

Length	2.30	mm.
Yolk-sac	1.00 × .65	"
Yolk-sac to vent	.25	"
Vent to tip	1.05	"
Width of head	.25	"

The time required for hatching varies from two to six days; and this difference of four days corresponds to a difference in temperature of 8° C.

For a description of the later stages, see Agassiz, Young Stages, etc. (Part III. pp. 290–294, Plates XIII.–XV.).

Tautoga onitis, Lin. (T. americana, Storer.)

Plates X. and XI. Figs. 1–12.

During the summer of 1884 experiments were made in artificial fertilization of the eggs of the Tautog, and in two instances with success. The early stages thus obtained form a very complete series, and they make it certain that Figs. 1–3, and probably Fig. 4, in Plate VI. of Agassiz's Young Stages (II. Flounders), belong to this species, and not to *Pseudorhombus melanogaster.*

The eggs of Ctenolabrus, *Ps. melanogaster*, and Tautoga all agree in having no globule; and their difference in size is not sufficiently great and constant to serve always as a safe guide to identification. The close resemblance of these eggs and their simultaneous occurrence make it very difficult, if not impossible, to distinguish them when promiscuously mixed, as they usually are when taken by surface skimming. Up to the time of hatching, and for some time afterward, the color, distribution, form, and number of chromatophores are so much alike in the three species that few distinctive marks can be named. At the time of hatching, Ctenolabrus has little or no pigment on the head, and may thus be distinguished from the Tautog, in which there is a continuous line of pigment encircling the front and sides of the head. Another but less striking difference is the extension of the pigment-dots farther backward in Ctenolabrus than in the Tautog, as will be seen by comparing Fig. 4 with Fig. 31 of Plate IX. The same distinctions hold between Ctenolabrus and *Ps. melanogaster*, if our identifications of the latter are correct. The Tautog is considerably larger and proportionally longer than the Cunner, as shown in the two figures just referred to. The eggs of the Tautog are most abundant in the early part of July, but they are also found in June and August. The eggs of Ctenolabrus occur in greatest abundance from the middle of May to the middle of June. The average size of these eggs is .88 to .89 mm., while those of the Tautog vary between .90 and .95 mm.

At the time the blastopore closes there is not a trace of pigment in any part of the Tautog egg. Soon after the tail has assumed the blunt rounded form and begun to lengthen backward (Fig. 1), minute black pigment-dots appear over the whole dorsal surface of the embryo. Different eggs vary considerably in the number of pigment-dots (Figs. 1–3). When seen from above, the dots often appear to be arranged in two lateral lines, one on each side of the chorda (Fig. 3). The dots are nearly round, and jet-black, and the largest are not more than .005 mm. in diameter.

In the newly hatched embryo (Fig. 4, sixty-six hours after fertilization) the dots have increased in size (.007 to .015 mm.), while remaining about the same in number. The longitudinal growth of the embryo has increased the distance between adjoining dots, and left the tail free from pigment. The continuity of the two lines of pigment around the head, which is characteristic of this and a number of the following stages, is well shown in Fig. 6. The yolk-sac, which is entirely free from pigment, has an ovate-elliptical

form. The vent is marginal, at some distance behind the yolk-sac, and a little behind the middle. Round white refractive bodies (nuclei?) are faintly seen over the entire surface.

Dimensions at the time of hatching: —

Length	3.05 mm.
Yolk-sac	1.00 × .48 "
Yolk-sac to vent	.55 "
Vent to tip	1.40 "
Width of head	.35 "
Width of body at hind end of yolk-sac	.15 "

Dimensions at twenty-four hours old: —

Length	3.25 mm.
Yolk-sac	.85 × .45 "

In the course of the first twenty-four hours after hatching, the chromatophores begin to expand, assuming a dendritic form. In this expanded state of the pigment the young fish appears quite dark (Figs. 7–10), and is easily seen if placed on a white ground. It requires only a few moments, however, to change the pigment from the expanded to the contracted form, when the fish again becomes as transparent as it was at the time of hatching. During the second day the yolk-sac becomes much reduced in size, the pectorals double their length, and the eye, already granular in its external half at twenty-four hours (Fig. 7), now shows a little green pigment.

Figs. 8–10 were all hatched from eggs fished up by surface skimming, and show the form and appearance of the pigment in somewhat different states of expansion. The wreath of cells seen on the head in these figures disappears in the later stages, leaving only a single large branched chromatophore on the snout (Figs. 11, 12). The remaining stages were taken with the surface net, and consequently we can state nothing definite in regard to their age; but their identity with this species is plainly shown by the character and distribution of the black pigment, and especially by the blue-green color of the eyes. The pale brownish-yellow appears first on the head and fore part of the body (Fig. 11), and becomes coextensive with the black pigment in the latest stage here figured (Fig. 12). The principal changes to be noted in these stages are the prolongation of the jaws, the tendency to heterocercality in the tail, and the increased width of the body.

Species allied to Motella.

Nos. 1, 2, 15.

Plates XII. and XIII.

Among the pelagic fish eggs occurring at Newport, one of the smallest and rarest is that figured in Plate XII. The average size of the egg is about .70 mm., ranging from .68 to .75 mm. The globule is comparatively large, measuring usually about .17 mm., but varying now and then from .165 to .175 mm.

The period of occurrence of these eggs is closely limited, so far as we have been able to observe, to the month of July, the earliest record being June 27, and the latest August 4. Within this period the egg was found only on nine occasions; and, with two exceptions, only two or three at a time. Thirty-six were obtained on July 19, and thirty on July 29. Among those of July 19, nine had from two to four globules each, the rest having only one. In every case where more than one globule was found, complete coalescence took place within twenty-four hours. As Fig. 1 of Plate XII. represents the youngest stage obtained, we are unable to say whether the occurrence of two or more globules is the rule in the earlier stages.

Although we have not been able to obtain a complete series of the stages of development, we have enough to warrant the opinion that this species is allied to Motella. The eggs which have been referred to Motella by Mr. Agassiz are a little larger (.75 to .84 mm.), with a single large globule (.15 to .16 mm.); while those of *M. mustella* are of about the same size, varying according to Brook* from .655 to .731 mm. (longest diameter). The size of the globule in *M. mustella* is stated by Brook to be only .11 mm., and this is remarkably small as compared with the eggs we have studied.

Our observations on the occasional occurrence of several globules and their ultimate coalescence to form a single globule, taken in connection with those of Brook, make it probable that both in the species under consideration and in Motella the fresh-laid egg has, normally, more than one globule. The presence of more than one globule is regarded by Brook as an abnormal development, which leads to irregularities often fatal to the development of the embryo; but this view is certainly not sustained by a comparative study of the occurrence of oil-globules in other species.

* Brook, George. Linnean Society's Journal. XVIII., 1885, p. 298.

The coalescence of two oil-globules has not been directly observed; but eggs having two or more globules have been isolated, and found later with a single globule equal in bulk to the several original globules. The process of coalescence does not require more than a few minutes, perhaps only a few seconds.

The successive stages in the development of this egg, so far as we have been able to follow it, have each a very characteristic pigment-marking. In the earliest stage of the series (Fig. 1), which is shortly after the closing of the blastopore, we find that the development of black pigment has only fairly begun. The pigment-cells of the yolk-sac are not numerous, and are mainly confined to the dorsal half, extending to the ventral half only in the region of the tail and near the globule. The pigment is now represented by small, round black dots, each dot marking the centre of a whitish amœboid cell. Pigment-dots are also distributed along the back of the embryo from end to end, in two irregular lateral lines.

Eighteen hours later (Fig. 2) the number of pigment-cells is about the same, but the black dots, which were only about .005 mm. in the previous stage, now measure about .02 mm., and nearly fill the cells. They are round, or angular, sometimes following the pseudopodial extensions of the cell. The distribution of pigment on the body is the same as in earlier stages. Scattered over the yolk-sac at this time are smaller clear cells, varying in shape, and without a trace of pigment. Fig. 5 represents a similar stage, somewhat more highly magnified, found by Mr. Agassiz at Nahant. The size of the globule, and the shape and distribution of pigment, leave no doubt as to its identity with the species found at Newport. Fig. 4 represents a stage intermediate between Figs. 1 and 2, showing two oil-globules slightly unequal in size. The two together are about equal in volume to the single globule which was found somewhat later in the same egg.

Forty-two hours after the stage seen in Fig. 1, we find the embryo ready to hatch (Fig. 3). The yolk-sac is much smaller, and the tail nearly reaches the head. The pigment-cells of the yolk-sac have scarcely changed in appearance, but are less numerous. On the other hand, the pigment-cells of the body, with the exception of a single cell on the tail, have assumed a form quite unlike that seen in the previous stages. They have expanded into large and beautiful dendritic forms. A few of these forms, grayish in color, with delicate processes, are now seen on the surface of the globule. A single large pigment-cell is found in front of each eye,

and twelve to fifteen small black dots in the posterior part of the eye. The caudal end is entirely free from pigment for a considerable distance. The pigment-cells of the body have also diminished somewhat in number, but may still be said to be disposed in two lateral rows. The same clear unpigmented cells are seen scattered over the yolk-sac.

A still further reduction of pigment is noticeable in specimens examined immediately after hatching, the black dots having entirely disappeared from the yolk-sac (Figs. 6, 7). The dots of the eye are a little more numerous, and usually blacker. The fin folds are wholly free, or nearly so, from pigment. The black spots scattered rather sparingly along each side of the body vary much in size and shape, presenting generally a coarse dendritic form. In this stage it is usual to find only a single large black spot in front and between the eyes, and a larger number of spots on the anterior than on the posterior half of the body. In Fig. 6 are seen a few pale yellow spots on the yolk-sac and anterior half of the body. In drawings of an earlier date these spots do not appear; but they were most likely overlooked, as they are quite inconspicuous. The entire surface presents a rough aspect due to peculiar granular cells.

Characteristic of this species, as well as of *Motella mustella* * and *Gadus morrhua*,† is the termination of the alimentary tube on the *side* of the ventral fin-fold, instead of at its margin.‡ The canal appears to open to the exterior, but we are not positive that this is so at this stage of development. No external opening appears in *M. mustella*, according to Brook, until a much later date.

The following measurements are from the specimen shown in Fig. 6: —

Total length	2.30 mm.
Length of yolk-sac	.75 "
Width of yolk-sac	.375 "
From yolk-sac to vent	.12 "
Vent to tip	1.20 "
Height at middle	.60 "
Width of head	.325 "

The yolk-sac, seen from above or below, has an ovoidal form.

Figs. 10 and 11 represent the young fish about twelve hours after hatching. The pigment-dots have increased in number and size in the eye until

* Brook, *loc. cit.*, p. 304.

† Ryder, John A. "A Contribution to the Embryography of Osseous Fishes," p. 78.

‡ Agassiz (Young Stages, etc., Part III. p. 290) calls attention to the same peculiarity in the young Spanish Mackerel (*Scomberomorus maculatus*, J. & G.).

the posterior half is quite black. In this specimen are seen the two spots in front of the eyes which were first seen in the stage of Fig. 3, and which in many cases become confluent. The number of spots on the body is now reduced to twelve or fifteen, the most prominent of which are the anterior and posterior pairs.

The reduction in the amount of pigment reaches its minimum in Fig. 9, twenty-four to thirty-six hours after hatching. The disposition of the pigment-cells now plainly anticipates conditions that characterize all the later stages that have come to our notice. The posterior spots, of which there are here three, hold a position about midway between the vent and the tip of the tail, at the upper and lower angles of the muscular myotomes. In the later stages these spots multiply both above and below (more above than below), forming thus two elongated patches of more or less confluent cells. There is now a row of four prominent pigment-cells along the middle third of the alimentary tract, on its dorsal wall. These cells also increase in number, forming in later stages a continuous streak from the level of the base of the pectorals to the vent. The spot on the head is small, and is destined to disappear. In another specimen of about the same age (Fig. 8) this spot is missing, or perhaps has only shifted its position to a point between the eyes and a little behind them, where a single large dendritic cell is seen. Five similar cells lie on the alimentary canal, and a much larger one is placed at the end of the second third of the body. The eye is now entirely black.

Fig. 12 represents a specimen twelve days after hatching, the oldest stage raised from the egg. The three distinct regions of black pigment, already marked out at the stage of twenty-four hours, are here well defined. The eye now shows a circle of blue around the pupil, and the head and anterior half of the body are colored with a diffuse pale brownish-yellow. The termination of the alimentary canal is still far from the margin of the ventral fin-fold, but it is not on this account to be assumed to be closed.

The remaining stages were fished up from the sea, and their specific identity with the young raised to the stage of Fig. 12, although not certain, is quite probable, as may be seen from the character and distribution of the black pigment. In the stage of Fig. 13, captured August 13, there was no trace of the pale tint of Fig. 12, nor of the brighter yellow of Figs. 14 and 15. The ventrals were first recognized in the stage of Fig. 15 (August 31, 1875). A somewhat older specimen was found, July 20, 1884, in which the ventrals were longer, but entirely free from pigment.

The Sense-organs of the Lateral Line. — There are one or two points relating to the structure and distribution of these organs to which we would here briefly call attention, since they appear to bear directly on the questions of their morphological and physiological significance. These organs are usually described as furnished with delicate hairs, which certainly gives a very inadequate notion of the picture they present in the living fish. Instead of a tuft of distinct hairs, we find a very delicate and perfectly transparent membranous extension, of such extreme tenuity that it presents only a shadowy outline. It is only in the base of this membranous extension that hair-like thickenings are recognizable; and these thickenings, tapering outward, vanish at a short distance from the rounded summit of the sense-bulb, beyond which point there is not the faintest indication of hair-like structure, and only now and then a minute granule to break the almost perfect homogeneity of the membrane. While this terminal portion of the sense-organ may be described as a strap-shaped appendage ("cupula terminalis," Solger), somewhat resembling the tiny locomotive flappers of a Ctenophore, it is to be remembered that it becomes thicker and more columnar at its base. If one of the sense-organs be viewed *en face*, it will be seen that the hair-like thickenings of the columnar portion of the appendage are evenly distributed over its summit. Ontogenetically considered, this appendage may be regarded as a tuft of coalesced sense-hairs.

Our description of it is based upon a careful examination of the structure in living and healthy specimens. In specimens injured by pressure or otherwise, the more delicate, thinner portion of the appendage is soon lost, leaving the basal portion with its thickenings looking more or less like disconnected hairs.

In this species there are four pairs of these sense-organs symmetrically placed on the sides of the head, and from four to five pairs on the body, of which usually only the first two are metamerically disposed, the rest being, strictly speaking, unpaired, those of one side alternating at longer or shorter intervals with those of the other side. The first pair is situated in front of and between the olfactory pits; the second, a little in advance of the eyes, and somewhat above the middle of the head in a vertical direction; the third, still higher up on the sides of the head, at some distance above the posterior portion of the eye; the fourth, a little lower down, barely above the posterior edge of the eye; the fifth, at the beginning of the second third of the total length, high above the plane of the lateral nerve; the sixth,

about midway of the body, as far below the lateral nerve as the fifth is above it; and the rest occur at unequal intervals, at about the same height as the lateral nerve. The location of these organs at different heights, and the more perfectly preserved bilateral symmetry of those on the head as compared with those on the body, are points to which we shall recur again presently.

The first and fourth pairs of sense-organs are very conspicuous, and are easily seen from all sides, while the second and third can only be seen well when the fish leans a little to one side. The chief irregularities in number, size, and position are found in the posterior sense-organs. The fourth pair is in a favorable position for examining the membranous appendage, which measures from .18 to .20 mm. in length by .02 mm. in width. The width is nearly uniform, narrowing a little at the tip. It is perfectly straight, immobile, and perpendicular to the general surface.

As is well known, each of the sense-organs belonging to the body is supplied with a branch of the lateral nerve, the entire course of which can easily be traced in the living fish (Fig. 8).* In some of the young fishes of this species from twenty-four to forty-eight hours old, the skin stands out at some distance from the muscular axis, leaving a clear space, in which can be seen with remarkable distinctness the lateral nerve, and its branches leading to the organs of the lateral line. Such conditions were not observed in other species, nor were they the rule in this. The individuals here figured appeared perfectly healthy, and in all other respects normally developed. In such specimens, nerves (posterior roots of cranial nerves) could be traced to each pair of organs on the head except the first. The origin of these nerves could not, of course, be determined by surface examination; but judging from their direction, and from what is now known of the innervation of these sense-organs in Elasmobranchs,† we may assume that they represent the oculomotor, trigeminal, facial, and glosso-pharyngeal (which last, according to Mayser,‡ belongs properly to the vagus group). Thus, to the differences before mentioned between the sense-organs of the head and those of the trunk we have to add a more fundamental distinction in respect to nerve supply, each pair of the former being innervated by branches from a corresponding pair of segmental cranial nerves, while those of the latter are

* Ryder thinks that these organs are each supplied by separate nerves coming directly from the spinal cord (Embryography of Osseous Fishes, p. 55).

† Van Wijhe. "Ueber die Mesodermsegmente und die Entwickelung der Nerven des Selachierkopfes," Amsterdam, 1882.

‡ Zeitschr. f. wiss. Zool., XXXVI., pp. 303, 304.

supplied with branches from a single pair of nerves. In all respects, therefore, the segmental character of the sense-organs has been more perfectly preserved in the head than in the trunk. These differences must, however, be regarded as secondary in origin, for there can no longer be any doubt, if any has existed since the investigations of Stannius* and of Solger,† that these sense-organs are segmental. This point is conclusively established by their developmental history, for a knowledge of which we are indebted to the recent investigations of Beard.‡ In the case of *Salmo fario*, according to Beard, the lateral organs make their appearance first as a cord of cells derived from the inner epiblastic stratum, extending from the region of the neck along the whole length of the body at the height of the chorda. In every segment are formed thickenings of this cord of cells, which give rise to the sense-bulbs of the lateral line. For the first two or three months these sense-bulbs are seen as protuberances on the free surface of the epidermis, but soon after the disappearance of the yolk-sac they are shut off from the surface by the development of the so-called "mucous canals." Many of the primitive epiblastic thickenings are not carried to the stage of fully developed sense-bulbs, but disappear in early stages by atrophy. It is in this way that the metameric arrangement of the permanent bulbs becomes obscured.

Starting then with the fact that the lateral-line organs are undoubted segmental sense-organs, how are we to explain their position at different heights? Is this the result of a shifting of position, or may it be regarded as an evidence that these organs were originally arranged in several rows on each side of the body? It has long been taken as a matter of course, that the different patterns of arrangement were to be referred primarily to one, in which there was only a single row on each side. The discovery of such a type among the Annelids by Eisig has tended to confirm this idea. This view will have now to be reconciled with the fact that in one large group of Annelids, the Hirudinidæ, there are from twelve to fourteen distinct rows of segmental sense-organs. There are some reasons for believing that this arrangement is more primitive than that seen in the Capitellidæ, but they cannot be dealt with here. In case this suggestion be well founded, the occurrence of more than one lateral line, as is the case in some fishes, might be explained on other grounds than a multiplication by division.

* Stannius. "Das peripherische Nervensystem der Fische," Rostock, 1849.

† Solger. "Neue Untersuchungen zur Anatomie der Seitenorgane der Fische," Arch. f. Mik. Anat., XVII. and XVIII., 1879–80.

‡ Beard. Zoolog. Anz., VII., No. 161, 1884, p. 123.

The observations of Malbrane* and Beard, according to which more than one pair of these organs may occur in a single segment as the result of a division of a primary pair, we have not been able to confirm. We have seen cases in which there were apparently two of these organs in close proximity, neither of which was perfectly developed. In no case have we found two well developed side by side. The occurrence of three lateral lines in some Flounders, and the occurrence of the same number, as a rule (Malbrane), in Amphibians, is not easily explained as a result of the division of one line, but is precisely what might be expected if the view above suggested is correct. The same view would also offer a ready explanation of the position of these organs at different heights, as shown in the species here described. The sense-organs of the body and tail represent three series, which we may designate as dorsal, ventral, and intermediate. The dorsal and ventral series are each represented by a single organ, while the intermediate is represented by from two to three. The dorsal and ventral series are developed in the middle region of the trunk, and the intermediate series only on the tail. Precisely the same arrangement is seen in Fierasfer.† A comparison of our figure and that of Emery with Malbrane's Plate I., Fig. 10, representing a young Axolotl, will show that the view above presented is not without support.

There are undoubtedly more than one series represented in the lateral-line organs of the head; but here the arrangement gives no clue to the precise number of series.

Although we have seen no direct evidence of a multiplication by division among these organs from the studies of Malbrane on Amphibia, such a mode of development is very probable. But allowing this to be true, it is evident that it does not offer a satisfactory explanation of the presence of three or more distinct segmental series; and it accords quite as well with the view that there were originally several series of lateral-line organs, as with the commonly received opinion that there was but one series.

The important discovery made by Mayser,‡ that the nervus lateralis vagi (Stannius) is composed of two kinds of fibres, representing the recurrens superior and the posterior root of the acusticus (N. VIII. post.), goes far towards deciding the question of the function of the lateral-line organs as

* Malbranc, M. "Von der Seitenlinie und ihren Sinnesorganen bei Amphibien," Zeitschr. f. wiss. Zool., XXVI., pp. 76–80.

† Emery, Carlo. Fauna und Flora des Golfes von Neapel. II. Monographie: Fierasfer. (Fig. IX. p. 43.) 1880.

‡ Mayser, P. "Vergl. anat. Studien üb. d. Gehirn d. Knochenfische," Zeitschr. f. wiss. Zool., XXXVI., 1881, pp. 309–311.

accessory organs of hearing, and at the same time towards confirming the serial homology of the ears with these organs, as maintained by Beard. Leydig was the first to call attention to the similarity in structure between these two classes of organs.

The Sienna Flounder.

Plates XIV. and XV. Figs. 1–14.

Figs. 1 to 3 of Plate IX. in Agassiz's Young Stages of Osseous Fishes (II. Development of the Flounders) belong to this species, which we may designate as the Sienna Flounder. But the remaining stages figured on that plate (Figs. 4–7) belong to another species, which we may call the Transparent Flounder (*Pseudorhombus oblongus*, Stein). The egg of the Transparent Flounder is distinguished from that of the Sienna Flounder by having no oil-globule, and no pigment on the yolk. In these respects, as well as in size and general appearance, the egg agrees with that of the Tautog; but the young fish at the time of hatching is distinguished from the Tautog of the same age by its highly arched dorsal fin-fold, and by the position of the vent, which is placed somewhat farther back.

The average size of the egg of the Sienna Flounder is .95 mm., and its oil-globule varies but little from .15 mm. From one to a dozen or more are usually found daily during the summer months. The colorless chromatoblasts make their first appearance on the dorsal side of the embryo and yolk-sac, at the time when the closing of the blastopore is wellnigh completed (Fig. 1). Just after the closing (Fig. 2) we find that the chromatoblasts are still uncolored, but more numerous, and a few of them present from one to three short, fine pseudopodial elongations. The body of the embryo shows a faint trace of diffuse yellow.

Shortly after the tail has begun to extend beyond the yolk, minute round black dots begin to appear in some of the chromatoblasts, and these become quite numerous by the time the stage of Fig. 3 is reached. At this time, however, there is a considerable number of additional chromatoblasts in which no black dot has appeared. The same is true of the stage of Fig. 4, in which pale yellow chromatophores have become quite numerous, especially on the tail. Fig. 5 shows a stage just before hatching, in which the development of yellow pigment was not so far advanced as in the preceding stage (Fig. 4).

At the time of hatching, the small round black dots (.005 mm.) are few in number, and nearly evenly distributed over the yolk-sac and the entire body and head. In front of the end of the tail a few of these dots are seen on the embryonic fin-fold, both above and below the muscular axis. The yellow chromatophores are rather more numerous, and from two to three times as large (.01 mm. or more) as the black dots. The yolk-sac shows only a few of these yellow cells along each side of the body, and none on the ventral half. The globule has one or two yellow dots to ten or more black ones. The yellow chromatophores are evenly distributed over the head and trunk, but stop short in front of the end of the tail. On the dorsal fold they form a single row along the margin of the middle third; half-way between the vent and tip they form a loose cluster, both above and below the axis of the tail. Only two or three are to be seen on the ventral fold between the vent and the loose cluster. After hatching, the color varies considerably from hour to hour, according to the contracted or expanded state of the chromatophores. Fig. 6 (12 hours) shows both the yellow and the black cells in a state of maximum expansion. The yellow pigment of the dorsal fold appears in the form of brownish yellow blotches, and the whole body has a diffuse bright yellow hue. The black pigment-cells have a rather coarse dendritic form, and the caudal cluster on the ventral side has assumed a linear arrangement.

The dimensions of the young fish of twenty-four hours are as follows:—

Length	3.10 mm.
Yolk-sac	1.00 × .35 "
Yolk-sac to vent	.20 "
Vent to tip	1.55 "
Height (at middle of yolk-sac)	.55 "
Width of head	.325 "

In specimens of this age the black chromatophores are more or less angular or branched, but much smaller than in the specimen of twelve hours (Fig. 6). They usually preserve the uniform distribution seen at the time of hatching. The yellow cells, on the contrary, exhibit a remarkable power of expansion, especially on the body; and on the embryonic fold they concentrate into irregular, more or less brownish patches, which vary much in size, shape, and number. Their more typical arrangement is that seen in the stage of Fig. 8 (60 hours). Three blotches hold a marginal position near the middle of the dorsal fold; four are placed about half-way from the vent to the tip, two above and two below; and two more, one dorsal and

one ventral, are seen nearer the end of the tail. In Fig. 7 (36 hours) the first three blotches are represented by a continuous streak, and the same is true of the next two on the dorsal fold, as well as of the three on the ventral fold. A similar concentration, carried still further, is seen in Fig. 10 (about 84 hours), where the first three blotches are wanting. In Figs. 11 (60 hours) and 12, these spots are still distinct, while in Figs. 13 and 14 they are reduced to two. In the course of the third day a blue pigment appears in the eye (Fig. 11), which characterizes the remaining stages here figured.

The granular cells, seen on the tail of Fig. 7, extend over the entire surface, and are present in the later stages, becoming somewhat larger and more opaque as the fish grows older.

This fish is comparatively long at the time of hatching, and the embryonic fin-fold is narrow, seldom arching as in Figs. 7 and 11. The vent is marginal from the first, and is placed a little in front of the middle.

Pleuronectes americanus, Walb. (**Platessa plana**, Storer.)

Plate XVI. Figs. 1–10.

One of the most common eggs found at Newport in July and August is that referred by Mr. Agassiz to the above species of Flounder. The stages connecting this egg with *P. americanus*, the later stages of which are described in "The Young Stages of Osseous Fishes," * were only satisfactorily identified during the early part of July, 1884; and this explains our inability to assign more precise limits to the period of occurrence. This egg resembles in many respects that of Ctenolabrus, and was confounded with it to the date above given. There is little doubt that the egg occurs during a large part of June, and perhaps as early as May.

The average size of the egg is a little over .80 mm.; but it varies considerably, ranging between .78 mm. and .90 mm. The egg is perfectly transparent and colorless, and has no oil-globule. A much smaller egg (.70 mm. or less), presenting in other respects identical characters with this species, was occasionally found (Fig. 1). We were unable to obtain many stages of this small egg, and must therefore leave the question of its identity unsettled.

The pigment makes its appearance about the time the blastopore closes, in the form of small rounded black dots (.005 mm. in diameter), arranged in

* Agassiz, Alexander. "Development of the Flounders," Proc. Amer. Acad. Arts and Sciences, XIV., Plates III., IV., and V., 1878.

two more or less regular lateral lines on the dorsal surface of the embryo (Figs. 1 and 2). The dots do not extend to the anterior half of the head, nor to the tip of the tail. No pigment is found on the yolk-sac in any of the stages here described. Kupffer's vesicle vanishes soon after the closing of the blastopore, as in most of the other species we have examined. With the growth of the embryo the pigment-dots increase somewhat in number and size, without becoming very numerous, reaching their maximum development about the time of hatching (Figs. 4 and 5). The embryo has a flat spoon-shaped head and a comparatively long body, the tail reaching the head, and sometimes overlapping it, just before hatching. These characters serve to distinguish the embryo from that of Ctenolabrus.

At the time of hatching, the pigment is similar in form to that of the young fish of twelve hours (Fig. 5). The majority of the chromatophores are still rounded dots (.006 to .010 mm. in diameter); those on the head and fore part of the trunk exhibiting thread-like elongations. The yolk-sac has an oblong elliptical form; this is another feature distinguishing this species from Ctenolabrus. The following measurements were taken from a newly hatched specimen: —

Total length	2.85	mm.
Yolk-sac	.85 × .35	"
Yolk-sac to vent	.45	"
Vent to tip	1.45	"
Width at head	.30	"
Width at otic capsules	.20	"

Twenty-four hours after hatching, the black dots have nearly all vanished, leaving four black patches, which characterize the remaining stages. One of these patches is seen just above and a little behind the middle of the yolk-sac, a second near the vent, a third half-way from the vent to the tip of the tail, and a fourth near the end of the muscular axis. These spots are all located on the ventral side of the body, and only rarely extend dorsally, as in the case of the third spot in the specimen represented by Fig. 8.

Dimensions at twenty-four hours: —

Length	3.00	mm.
Yolk-sac	.75	"
Yolk-sac to vent	.50	"
Vent to tip	1.55	"
Width of head	.35	"

The yolk-sac has still the oblong elliptical form, and the granular aspect of the eye, just appearing in the stage of Fig. 5, is now complete.

Figs. 6 and 7 represent specimens somewhat older (about 30 hours); the yolk-sac reduced in size. The transverse bars of black pigment seen in Fig. 6 are unusual; the more typical arrangement of pigment at this stage is that given in Fig. 7.

The eye begins to turn green at the age of thirty-six hours, growing darker and assuming a coppery hue in later stages (Figs. 8 and 10). The surface of the fish becomes granular as early as the stage of Fig. 6, and from this time appears as represented in the middle and posterior portion of Fig. 9.

The pectorals are quite transparent, and develop comparatively slowly in these earlier stages (compare Plate XVI. figs. 7–10).

Species No. 10.

Plate XVII. Figs. 1–3.

Only four eggs like that represented in Fig. 1 have been obtained, and these were found in the early part of June, 1884. With one exception (Lophius) this is the largest among the pelagic fish eggs occurring at Newport. The egg measures 1.15 mm. and the oil-globule .28 mm.

The entire outer surface of the body is clothed with a rich layer of black dendritic chromatophores, only the fore part of the head and the end of the tail being free from them. The same cells also thickly envelop the oil-globule. A few clusters of bright yellow cells are characteristic of this stage; the largest and most conspicuous are two seen at the inner posterior angles of the eyes. Two much smaller ones are placed on the ventral surface near the base of the tail. Another small cluster is seen near the middle of the body in this specimen, but it is not constant. At this time may be seen on different parts of the yolk-sac a few peculiar unpigmented cells, the nature and history of which were not ascertained.

We did not succeed in hatching any one of these eggs, and their association with the stages seen in Figs. 2 and 3 is therefore purely a matter of conjecture.

Fig. 2 represents a young fish, which, from the size of the yolk-sac, must be at least three or four days old. The black pigment now appears in the form of large branching cells, of which two have a median dorsal position above the mid-brain and oblongata, from four to six clasp the upper side

of the intestine, and the remaining four, in two pairs, divide the tail into thirds. The same regions are marked by diffuse bright yellow pigment, which extends to the yolk-sac and different parts of the head. The eye is greenish blue, with a metallic reflection. Elsewhere the fish is perfectly transparent. The vent is on the side of the fin-fold, close to the muscular axis.

The next stage (Fig. 3) shows less yellow and more black pigment. The distribution of the latter remains nearly the same, a single spot having been added near the end of the tail. The black pigment-spots have greatly increased in size. The vent has now a marginal position. A large black pigment-spot is seen at the base of the pectorals, the long straight rays of which spread out fan-like in the distal portion of the fin. The eye has a very light greenish tinge.

Osmerus mordax, Gill.

Plate XVII. Figs. 4, 5.

Two or three eggs of this species are usually found every season at Newport. The egg is remarkable on account of the complete segmentation of the yolk, as shown in Fig. 4. The yolk and embryo are quite transparent, and the yolk-segments are large and clearly defined in the living egg. Sections of the hardened egg have not demonstrated the presence of nuclei in these segments, and no stages thus far obtained give any clue to the time or mode of their origin. The egg is somewhat oval in shape, measuring .75 by .80 mm. The embryo attains a remarkable length before hatching, reaching about 5 mm.; and the yolk-sac of the newly hatched embryo is many times smaller than in the stage of Fig. 4. Frontal and profile views of the young fish just after leaving the membrane are seen in Figs. 5 and 6. No trace of pigment appears in the egg, nor in the young fish until it attains a length of about 9 mm. The stage represented in Figs. 5 and 6, and a number of later stages, have been described by Agassiz* as follows: —

"The young on hatching are about 5 mm. in length, with a comparatively small yolk-sac, very rudimentary head, huge eyes, the vent placed at about three quarters of the length of the body near the posterior extremity, pectorals quite rudimentary. There are no pigment-cells in this stage in

* Agassiz, Alexander. "Young Stages of Osseous Fishes," Part III. p. 297, Proc. Am. Acad. Arts and Sciences, XVII., 1882.

any of the young I have collected. In the next stage figured (Pl. XII. fig. 3), the young fish has greatly changed; the head is quite elongate, branchiæ are present, the lower jaw projecting beyond the upper one, pectorals large, eye brilliant emerald-green, the yolk-sac has completely disappeared, the caudal embryonic fin-rays are very marked; we can also see the first trace of the separation between the caudal, anal, and dorsal. A prominent row of large pigment-cells extends along the base of the anterior anal embryonic fin-fold, with a smaller line extending along the upper side of the intestines, a few small pigment-cells at the extremity of the notochord, along the base of the posterior anal and of the operculum, with two or thre pigment-cells along the dorsal line about half-way from the head to the tail.

"In the next stage figured, the young Osmerus is considerably older, measuring already 22 mm. in length; the caudal is completely separated from the dorsal and anal, in both of which the permanent fin-rays already exist; there are rudimentary ventrals present in this stage. The general coloring of the body is a light dirty yellow, with patches of more brilliant yellow along the lateral line and base of the head. There is one line of grayish pigment-spots along the dorsal side of the notochord, a very prominent line of large pigment-cells running somewhat below the notochord, extending from the base of the pectorals to the vent, with four or five large pigment-cells along the base of the anal and the ventral line towards the base of the caudal. Small pigment-spots extend along the base of the caudal fin-rays, with three or four larger spots at the base of the caudal fin. The oldest stage I have found (Pl. XII. fig. 5) was not larger than Fig. 4 (Pl. XII.); but the caudal, anal, and dorsal were in a more advanced condition, the permanent fin-rays better marked, the head less elongate, the body behind the ventrals comparatively broader. The great resemblance of this stage of Osmerus to Scomberesox and Belone in the general arrangement of the median fins and the great elongation of the body is striking. Mr. H. J. Rice has, in the Report of the Commissioner of Fisheries of Maryland for 1877 (Plates III., V.), given excellent figures of several young stages of the Smelt. The figures here given complement the stages already known, and with those of Mr. Rice give a fair sketch of the principal changes of the Smelt due to growth. The resemblance of the development of Osmerus to that of the Herring, as given by Sundevall, is very striking. Sundevall figures young fishes, which he calls embryo Herring, from 8 to 38 mm. in length, but he does not state whether they were actually raised from eggs of known

origin. Before the publication of Mr. Rice's paper, I supposed the young fishes figured on Plate XII. to be the young of some Clupeoid, but the figures given by him seem to leave no doubt that the young I figure on Plate XII. belong to the Smelt."

Motella argentea, Rhein.

Plate XVIII. Figs. 1–6.

The eggs of this species were found, during the summer of 1884, from May 25 to July 25, but only on comparatively few occasions, and rarely more than one or two at a time. It is by no means certain that this species has been correctly identified, as no intermediate stages connecting Fig. 6 with the earliest stage described by Mr. Agassiz * have been obtained, and as some uncertainty still remains with regard to the genus to which the specimens formerly referred to Motella belong. In connecting this species with that described by Mr. Agassiz as *M. argentea,* we have to rely mainly on the character and distribution of pigment in the newly hatched fish (Fig. 6), and in a less degree on the size of the egg, presence of an oil-globule, and the long and rather slender form of the embryo.

The egg of this species is small, though a little larger than that of the allied species described in Plate XII. The average size is about .78 mm., the smallest measurement recorded being .75 mm. and the largest .84 mm. The globule is comparatively large, and colorless, and measures in most cases .15 mm., reaching .165 mm. in a single case. Two globules were found in one egg, which soon coalesced, forming one of the usual size. July 13, a similar egg was obtained, containing two cupreous-colored globules. The egg measured .77 mm., and the globules, after coalescence, .16 mm. This egg probably belonged to a different species, but the development was not followed, so that we are unable to give further data for its identification.

The egg of *M. mustella,* according to Brook,† varies from .655 to .731 mm. (longer axis), and the oil-globule is only about .11 mm. In one lot of eggs laid in an aquarium, the majority were found to have more than one globule, and in every case of this kind the several globules coalesced before the embryo hatched. As the eggs of this lot showed an unusual number of irreg-

* Agassiz, Alexander. "On the Young Stages of Osseous Fishes," Proc. Amer. Acad. Arts and Sci., XVII., p. 294 (Plate VII. fig. 1).

† Brook, George. "On some Points in the Development of *Motella mustella,* Linn.," Linnean Society's Journal, XVIII., 1885, pp. 298–307.

ularities in the early stages of development, Brook concluded that, "directly or indirectly, an abnormal development of the oil-globules has its influence on the development of the embryo." It is evidently assumed that the normal number of globules is one for all stages of the egg; but the author has not given satisfactory grounds for this opinion, and what he has given appears to us to furnish some foundation for thinking that the normal number is variable for the earlier stages, and one for the later stages. Our observations on this and other species suggest this view, but do not give the data necessary to decide the question.

The earliest indications of pigment-cells are seen while the last trace of the blastopore is disappearing (Fig. 1). At this time a few small, more or less angular, colorless cells appear in the posterior region of the embryo, and these are at first free from pigment. They increase rapidly in number, becoming slightly dusky from the presence of minute pigment-granules as the closing of the blastopore becomes complete. The development of the chromatophores progresses from behind forward, reaching the posterior boundary of the head in the course of six hours, as shown in Fig. 2. At this time the anterior chromatophores are the youngest, and still without pigment, while those at the posterior end are larger, amœboid in form, and already blackish with pigment. Between these two points all intermediate stages of growth are seen. Anteriorly, the pigment is confined to the dorsal surface of the embryo; posteriorly, it extends beyond the embryo to the yolk-sac and the oil-globule. The ventral side of the embryo and yolk-sac is without pigment-cells of any description.

It is about this time (forty-eight hours after being laid) that the pectorals make their first appearance, as lateral muscular thickenings, at a little distance behind the head. These thickenings correspond in length to two segments, and each is more or less plainly marked off into an anterior and posterior half, the line of division corresponding to the dividing line of the segments from which they originated.

Fig. 3 represents the same egg twenty-four hours later. The black pigment now appears rather coarsely branched, thickly scattered along the whole dorsal surface of the embryo. About a dozen chromatophores are now seen on the dorsal side of the yolk-sac, along the sides of the embryo. None are found on the ventral half, except around the oil-globule. Most of the chromatophores are wholly or in part jet-black; along the back some are lead-gray, giving the embryo a dusky or inky hue.

In the course of the next twenty-four hours (Fig. 4 is about four days old) the chromatophores become more crowded with pigment-granules, while retaining the general shape, size, and distribution seen in the previous stage. They are pretty evenly sprinkled over the whole free surface of the embryo, but when seen from the ventral side they appear to form two dense lateral streaks of stellate or dendritic cells. A rich network of finer-branched lead-gray chromatophores surrounds the oil-globule. By this time a few pigment-cells may be seen on the inner or ventral surface of the embryo, and only two remain on the yolk-sac. In another egg, at a like stage of development, no pigment was found on the yolk, and the chromatophores exhibited a dendritic form only on the tail and oil-globule, elsewhere having a rounded or angular form, varying in size from .008 to .015 mm. Eighteen hours later the pigment had not advanced beyond the stage of development seen in Fig. 4, although the embryo was much longer, the tail nearly reaching the head.

The next stage (Fig. 5 is about five days old) represents the embryo about twelve hours before hatching. The tail now overlaps the head, and the median fin-folds are well developed. The pectorals are also well advanced. The localization of pigment is already in progress, which in the course of another twenty-four hours is to end in the peculiar pattern seen in Fig. 6. The posterior half of the eyes is thickly dotted with black. A few large dendritic cells are seen on the head, a much larger number along the alimentary tract, another cluster at the middle of the tail, and a single spot near the end of the tail on the ventral side of the muscular axis. The concentration in these different regions only becomes more pronounced in the next stage, representing the same embryo twelve hours after hatching (Fig. 6). The whole eye is now jet-black, with a reflection of green in some parts. The alimentary canal is sheathed in a dense layer of black chromatophores; a broad black patch is located midway between the vent and the tail, a much smaller spot is seen near the tip, and a paler patch just above the hind end of the alimentary tube. Three or four less conspicuous spots are seen on the head, and two small pigment-cells close to the otic capsule. Elsewhere the young fish is pure transparent white. The oil-globule is still covered with pigment, and much reduced in size. The vent is at the hind end of the yolk-sac, high up on the ventral fold. The following measurements were taken from this stage: —

Total length	2.35 mm.
Length of yolk-sac	.55 "
Width of yolk-sac	.30 "
Width of same at hind end	.175 "
Width of head	.35 "

The time of hatching varies, according to temperature, from three to six days. The development of the pigment appears to be more backward in some specimens than in those above described. In one case the newly hatched fish has the eyes pigmented as in the stage of Fig. 5, and the body pigment in a stage of concentration scarcely advanced to this point. In this specimen the two characteristic caudal spots were present, but the patch above the vent was not yet indicated.

In the egg of this species there appears to be no Kupffer's vesicle, at least none was seen in any of the stages we have described. In this respect the egg differs from all the others described in this memoir. On this point, Brook remarks: "Kupffer's vesicle, which in Trachinus appears before any protovertebræ are formed, and long before the closure of the blastopore, does not make its appearance in Motella until at or after the closure of the blastopore, and at a time when there are at least six or eight protovertebræ. . . . The vesicle consists of a *solid mass of rounded cells*, which increases in size with the formation of the intestine, and gradually disappears again as the latter is pushed backwards towards the tail." If the cluster of bodies or "rounded cells" are veritable cells, it is evident that they are not to be confounded with a vesicle that never shows any trace of cell-structure. Judging from their time of appearance, and from their general aspect as described and figured by Brook, it seems probable that these bodies represent a cluster of vesicles, analogous perhaps to Kupffer's vesicle, yet not representing it. In our Preliminary Report * we have called attention to similar appearances that are of common occurrence in nearly all pelagic fish eggs. We have described these under the name of "secondary caudal vesicles." In appearance these vesicles differ little, if at all, from Kupffer's vesicle, and before learning the history of the latter we were in doubt about the independent nature of the former.

In the absence of anything that can be properly identified with Kupffer's vesicle, this species agrees with *M. mustella*. There is an agreement also in the time of occurrence of the eggs, and in the time required for hatching.

* Agassiz and Whitman. "On the Development of Some Pelagic Fish Eggs," Proc. Am. Acad. Arts and Sciences, XX., 1884, p. 73.

Brook has not described the young stages with a view to giving the development and distribution of the pigment in successive stages, and his figures therefore do not enable us to compare the two species in this respect. The arrangement of pigment-spots on the tail appears to be much alike in both species, but the stage seen in Fig. 6 is not shown in any figure of Brook's earlier than two and a half days after hatching (see Plate X. fig. 10).

The youngest specimen (4 mm. in length) of *M. argentea* described by Agassiz (*loc. cit.*, p. 294) differs already very widely from the latest stage here described, as will be seen from the following: "It was remarkable for the comparatively strong coloring for so young a stage. The head, the dorsal and ventral muscular lines, as well as the sides of the stomach, are of a dark, dirty yellow. The pectorals are large and transparent; but the ventrals, already well developed, are of a dark maroon color. The lower part of the eye is light blue, the pupil of a dark crimson. About half-way between the tail and pectorals there are two large pigment-cells, one in the dorsal, the other in the ventral side of the muscular axis. A small cell indicates the position where the embryonic caudal fin-rays are forming."

Species No. 23.

Plate XVIII. Figs. 7–10.

The material for the stages here described was obtained during the first half of July (1884). Only one or two eggs were fished up at a time, and the whole number thus obtained did not exceed half a dozen. With this scanty material we were unable to determine the species to which the eggs belong; but the stages described may be of some service for future identification.

The egg measures .94 mm., and its oil-globule .17 mm. In the earliest stage obtained (Fig. 7) the yolk-sac is entirely free from pigment; but the embryo is marked with a few round black dots, thickest along the middle region, and eight conspicuous clusters of yellow pigment-cells. The black dots are confined to the dorsal surface, while most of the yellow spots are on or near the ventral surface. The yellow spots invariably present the characteristic paired arrangement seen in Fig. 7. The first pair is placed close behind the eyes, the second a short distance behind the otic capsules, the third near the middle of the embryo, just above the hind edge of the yolk-sac, the fourth (dorso-ventral) midway between the third and the tip. In addition to these paired spots, there is a loose cluster of yellow pigment-

cells on the posterior edge of the globule, which may be regarded as an extension of the ventral spot of the posterior (fourth) pair; and a single spot, found on the median dorsal line opposite the third pair of spots, is not shown in the figure.

The arrangement of the yellow spots remains the same up to the time of hatching (Fig. 8.), by which time many of the cells composing the clusters have passed from the rounded into the dendritic form. The yellow cells on the globule are now scattered over its whole surface, and present both stellate and rounded forms. A single yellow cell is seen in front of the eye, and two finely branched black cells on the yolk-sac, none of which were present in the earlier stage. The black cells are less numerous than in the preceding stage, and are confined mainly to the dorsal angles of the segments. The dorsal and ventral fin-folds, and the posterior half of the tail, are not pigmented. The young fish is remarkably clear and transparent, and remains so through all the subsequent stages we have noticed. The ventral fold is broadly emarginate at a point a little behind the yolk-sac, where the vent is found.

The following measurements were taken from this stage: —

Total length	2.55 mm.
Yolk-sac	.85 "
Yolk-sac to vent	.125 "
Vent to tip	1.50 "
Width of head	.35 "

The yolk-sac is ovoid, the width of the larger end .525 mm.

Two days after hatching, the black pigment forms a complete network of delicately branched cells on the yolk-sac and oil-globule. Similar branching cells are seen on the head in front of the eyes, and two stellate cells are placed at equal intervals between the third and fourth sets of yellow spots. The black pigment-cells have diminished in number on the body, and multiplied on the yolk-sac, where they are somewhat more numerous than in the younger stage of another individual represented in Fig. 9. The yellow spots now have a duller hue, and in other respects present an aspect quite unlike that seen in the previous stage.

The cells now blend in an irregular massive form, from which numerous long, straight arms radiate in all directions, but with a marked preponderance to one side. The first spot clasps the posterior half of the eye, as shown in Fig. 9; the second sends strands in all directions, the

longer ones spreading fan-like towards the dorsal fold; the third encircles the body, its arms radiating downward from a dorsal centre, and upward from two lateral centres (the lateral centre is seen in Fig. 9 before expansion); the fourth (still in a contracted state in Fig. 9) also encircles the muscular axis of the tail. A few yellow pigment-cells are now seen on the yolk-sac, as well as on the oil-globule. Granular cells are also seen over the whole surface of the fish, a few of which are indicated on the median fold of Fig. 9, and more extensively on Fig. 10. The yellow spots seen in Fig. 9 contract, after passing through this stage of expansion, and again (at 50 hours) appear in the form of clusters of rounded cells.

In the next stage (Fig. 10 is about seventy-four hours old) we find the yellow spots much reduced, and apparently about to disappear altogether. A line of black chromatophores has developed along the ventral side of the tail, and round the eye.

Species No. 25.

Plate XIX. Figs. 1–7.

The stages here described were all obtained in the early part of July (1884). The species could not be determined; but the stages cover a very interesting period in the development of the pigment, extending from the time of closing of the blastopore until the young fish is four days old.

The largest number of eggs found at any one time was six. The egg varies in size from .81 to .90 mm., and the oil-globule from .22 to .23 mm. The globule is proportionally larger than that of any other egg described in this memoir, and its absolute size is exceeded only by the globule of the egg of Lophius and of No. 10. Two or three oil-globules were of frequent occurrence among the earlier stages; but they invariably coalesced in the interval of eighteen hours, which separates the stages of Figs. 1 and 2, forming a single globule of the ordinary size. The three globules represented in Fig. 1 coalesced while the drawing was making. The two on the left side coalesced first. The act was not seen, but it must have been quite sudden, as it occurred in the course of an interval of five minutes.

In the early stage of Fig. 1, just after the closure of the blastopore, we find two kinds of pigment-cells already fully developed in the embryo. Not a single pigment-cell is to be seen on the yolk-sac, in any of the stages before hatching; but the globules are well covered with chromatophores in all stages. The brownish yellow pigment-cells of the body are small,

rounded or angular, and thickest just behind the eyes and along the lateral surfaces. The black pigment-cells are of about the same size, usually angular, much fewer in number, and mainly confined to the median dorsal surface. On the inner surface of each globule are seen a considerable number of comparatively large, gray, amœboid cells, and on the outer surface a somewhat larger number of brownish yellow cells precisely like those on the embryo.

Eighteen hours later (Fig. 2), the pigment shows a much less uniform distribution, becoming concentrated into four regions. The black pigment of the body is now represented by a very few cells, and the gray pigment-cells of the inner surface of the globule have become yellow, and are only about twice the size of those on the outer surface. A large median space in the region of the otic capsules is without pigment.

The next stage (Fig. 3) is only a few hours older, but it represents another egg, in which the pigment-cells are somewhat larger and more deeply colored. The globule is now completely invested with pigment. The color is here a dirty sienna. This species bears a close resemblance to Hemitripterus in the color and density of its pigment, but is easily distinguished by the complete absence of pigment on the yolk-sac and by its large globule.

At the time of hatching, the concentration of the pigment in four regions is usually much better marked than would appear from Fig. 4, which is exceptional in not having any well-defined pigment region on the head and trunk. In another individual of the same stage the pigment-cells are mostly round and sharply defined, and distributed in a head region, a trunk region a little behind the otic capsules, an intestinal region at the posterior end of the yolk-sac, and a caudal region midway between the marginal vent and the tip. In Fig. 4 the chromatophores are in a state of expansion, giving a more diffuse coloring, which obscures the distinction between the head and trunk regions. In the individual above referred to there was no pigment on the yolk-sac, and only a few inconspicuous black cells scattered along the dorsal line of the middle third of the fish. This specimen was rather short, and the dorsal fold arched but little. The measurements of this stage are as follows: —

Total length	2.10	mm.
Yolk-sac	.75 × .50	"
Yolk-sac to vent	.10	"
Vent to tip	1.10	"
Width of head	.32	"
Width of body at vent	.15	"

The body tapers gradually from a point just behind the otic capsules to the end of the tail. The margin of the ventral fold is slightly notched at the vent.

The next stage (Fig. 5), twenty-four hours old, shows the chromatophores in a half-contracted state, distributed mainly in the four regions before named. There is a small admixture of black pigment, and the sienna pigment is now advancing over the yolk-sac.

At the age of seventy-two hours (Fig. 6) the entire yolk-sac is covered with sienna pigment and a few large, branching black cells. The head and trunk are diffusely colored, with stronger pigment-spots around the eye and front of the head. A coarsely branching spot is seen at the origin of the pectoral, and another above the pectoral. A streak of brownish and blackish spots runs along beneath the chorda from the pectoral to the caudal region of chromatophores. A single black cell is seen at the end of the chorda. The entire surface is now roughened with prominent granular cells, a few of which are sketched on the median folds.

The stage represented in Fig. 7 (four days) is so totally unlike the preceding stages that it is difficult to believe it is the same species. It is somewhat surprising that in both the species Nos. 23 and 25 the yellow pigment-spots should be followed by so different a coloration (compare Figs. 9 and 10 of Plate XVIII. and Figs. 6 and 7 of Plate XIX.). It will be interesting to see to what species these embryos belong. Something very similar in the variation of the chromatophores has been observed in successive stages of Ctenolabrus. The eye is now blue, and most of the pigment of the body has disappeared. The sienna pigment is represented by three or four patches of yellow, and the black by three coarsely branched cells about midway of the body and one large cell near the vent. This embryo has retained rather the embryonic fin-folds of earlier stages (Fig. 5) than those of the stage immediately preceding (Fig. 6).

To facilitate the identification of the different pelagic stages of Fish and Fish eggs, the following table has been prepared. It gives the most characteristic features of the egg and the young of each stage, with special bibliographical references.

Name.	No.	Egg.	Oil-Globule.	Occurrence.	Distinctive Features at Time of Hatching.	Plate.	Figs	Page.	Special Bibliographical References.
Cottus grœnlandicus, C. & V.	12	1 – 1.10^{mm}. Distinguished by the presence of many oil-globules.	10 – 40 in number.	June to Aug.	Many oil-globules; large, round, fleshy pectorals; wide embryonic fold; with one to four pigment-patches above and below; chromatophores of the body round, brownish yellow and black.	I.	1–5	7	A. Agassiz. Young Stages, etc., Part III., Pl. II. figs. 1, 2, and Pl. III., p. 285.
Species.	28	.63 × .65^{mm}.	.085^{mm}.	July to Sept.	Very little pigment; none on the yolk-sac, black and yellow dots on the body, a few small patches of black on the embryonic fold. Vent marginal.	I.	6–8	9	
Species.	26	.75 – .76^{mm}. Remarkably granular.	.14^{mm}. Brassy yellow.	July.	Color of oil-globule yellow, blue-black eye, two large black pigment-spots behind the vent.	II.	1–3	10	Compare with Plates XII. and XVIII. of this memoir. Compare also Kupffer, Beob. Journ. für Mik. Anat., 1868.
Hemitripterus americanus, C. & V.	7	1.02 – 1.10^{mm}.	.15 – .16^{mm}.	May to Sept.	Three large pigment-patches on the embryonic fold, two above and one below; body and yolk showing a rich development of brownish yellow pigment and black dots.	II., III.	4–12	10	
Blue-fish. Temnodon saltator, Lin.	22	Average size = .72^{mm}; varies between .66 and .84^{mm}. Distinguished by the partial segmentation of the yolk.	.17 – .23^{mm}.	June to Aug. Most abundant in last half of July.	Length 2.15^{mm}; no pigment on the embryonic fold or yolk-sac. Brownish yellow cells confined to anterior half or two-thirds of body; black pigment extends to near the end of the tail. Vent marginal, near the middle.	IV., V.	1–15	12	Agassiz. Young Stages, etc., Part III., Pl. II. fig. 5, p. 275. Verrill. U. S. Com. Fish and Fisheries, 1871–72, pp. 235–252. See also Van Beneden, E.
Lophius piscatorius, Lin.	19	1.75^{mm}.	.40 – .42^{mm}. Cupreous.	June to Aug.	A single (first) dorsal appendage, a small spatulate ventral, and a small circular pectoral; head and body transversely flattened; embryonic fold very wide; notochord straight; three or four black pigment patches at equal intervals along the lower, upper, and terminal parts of the muscular axis.	VI.	1–10	16	Agassiz. Young Stages, etc., Part III., Pl. XVI. figs. 2-5, Pls. XVII., XVIII., pp. 280–285. Ibid., Part I., Pl. II. figs. 9–12, p. 121. Günther. Introd. to Study of Fishes, p. 471. Emery. Fierasfer, Pl. I. fig. 2, Pl. II. figs. 5, 6.
Ctenolabrus adspersus, Walb.	20	.85 – .92^{mm}.	None.	May to June.	Comparatively short; few pigment-cells on the head; pigment extends to end of tail. Yolk-sac large, ovate.	VII. – IX.	1–34	18	Agassiz. Young Stages, etc. Part III., Pls. XIII.–XV. Ibid., Part I., Pl. II. fig. 7. Agassiz and Whitman. Preliminary Notice, Figs. 1–5. Kingsley and Conn. Embryology of the Teleosts. Brook. Development of Trachinus vipera, Linn. Soc. Journ., XVIII., p. 274, 1884.

Tautoga onitis, Lin.	17	.90–.95mm. A little larger than the egg of Ctenolabrus.	None.	June to Aug.	Continuity of the lateral lines of pigment on the head, forming a semicircular wreath; absence of pigment in the tail, embryonic fold, and yolk-sac.	X., XI.	1–12	21	Agassiz. Young Stages, etc., Part II. Flounders, Pl. VI. figs. 1–4.
Species.	1, 2, 15	.68–.75mm. Very large round black pigment-cells on yolk and embryo.	.17mm.	July. Rare.	Length 2.3mm; vent lateral; median fold unpigmented; large, coarse, black chromatophores scattered over the first two-thirds of body, and a few pale yellow cells on yolk-sac and fore part of body.	XII., XIII.	1–15	24	Cf. Brook, Linn. Soc. Jour., 1885. For arrangement of lateral line organs, see Emery on Fierasfer, 1880.
Sienna Flounder.	11	.95mm.	.15mm.	June to Aug.	A few small black dots distributed evenly over yolk-sac and the body; the yellow cells are more numerous and two or three times as large, and mainly confined to the body.	XIV., XV.	1–14	32	Agassiz. Young Stages, etc., Part II. Flounders, Pl IX. figs. 1–3. The remaining figs. (4–7) of the Plate belong to *Ps. oblongus*, Stein.
Pleuronectes americanus, Walb.	21	.78–.90mm. As a rule smaller than the egg of Ctenolabrus.	None.	July to Aug.	Pigment same as in Ctenolabrus, but the yolk-sac is smaller and oblong-elliptical. Longer and slenderer than Ctenolabrus.	XVI.	1–10	34	Agassiz. Young Stages, etc., Part I. Pl. I.; Part II. Flounders, Pls. III.–V. figs. 1–6. See also Malm, Pleuron. Utvik., 1868; and Steenstrup, 1864, K. D. Vid. Selsk. Forhandl.
Osmerus mordax, Gill.	18	.75 × .80mm. Oval. Yolk segmented.	None.	July to Aug.	Very long (5mm), with very small yolk-sac. Vent near posterior end. No pigment.	XVII.	4–6	37	Agassiz. Young Stages, etc., Part III., Pl. XII. figs. 1–5. H. J. Rice. Rep. Com. Fisheries of Maryland, 1877, Pls. III., V. Kingsley and Conn. Embryology of Teleosts, 1883, p. 188. See also Sundevall om Fisk. Utvick, 1855; and Kupffer, C., Entwickel. d. Heerings.
Species.	10	1.15mm. Two conspicuous yellow spots behind eyes. Black pigment profuse.	.28mm.	June.	None hatched.	XVII.	1–3	36	
Motella argentea, Rhein.	9	.75–.84mm.	.15mm.	May to July.	Posterior half of eye thickly dotted with black; vent lateral; pigment black, in characteristic patches arranged as follows: on the head and alimentary tract, one transverse patch at the level of the anus, a much larger one half-way from vent to tip, and a small hypaxial spot near the end of the tail.	XVIII.	1–6	39	Agassiz. Young Stages, etc., Part I., Pl. II. figs. 16–18; Part. III., Pl. VII., Pl. VIII. figs. 1–3. Brook. Development of *M. mustella*, Linn. Soc. Jour., XVIII., Pls. VIII.–X.
Species.	23	.94mm. Four pairs of bright yellow spots on the embryo. Scattered black dots.	.17mm.	July.	Yellow spots, one behind the eye, one behind otic capsule, one or two above the oil-globule, and one half-way from vent to tip; two or three finely branched black cells on yolk-sac, and black dots scattered sparingly along the dorsal line. Very transparent.	XVIII.	7–10	43	
Species.	25	.81–.90mm.	.22–.23mm.	July.	Very large oil-globule; brownish-yellow pigment (with a few black cells along the median dorsal line).	XIX.	1–7	45	

Name.	No.	Egg.	Oil-Globule.	Occurrence.	Distinctive Features at Time of Hatching.	Special Bibliographical References.
Siphostoma fuscum, J. & G. (Syngnathus peckianus, Storer).	29	.75 × .85^{mm}. Nearly opaque.	Numerous, orange-colored, measuring from .08^{mm} downward.	Aug.	About 200 taken from egg-pouch of male, Aug. 20, 1884, each measuring about 15^{mm} in length. Shape as in adult; marked with light brown patches at intervals.	Agassiz. Young Stages, etc., Part I. p. 121.
Fundulus heteroclitus, Günther (F. pisculentus, Storer).	24	Ovarian eggs (supposed to be mature or nearly so) obtained July 4; measured 1.85^{mm}. Contains, besides oil-globules, numerous light-colored spherules. Translucent.	Numerous, in a cluster; some scattered.	...	...	Agassiz. Young Stages, etc., Part III., Pls. XIX., XX. Dr. J. S. Kingsley found masses of 50 or more light yellow eggs in the sand, where Limulus eggs were found. The eggs were not identified, but the description given agrees closely with our description of the ovarian egg.
Pseudorhombus melanogaster, Stein.	5, 6, 13, 14	.90 - 1.00^{mm}. Very transparent, and easily confounded with those of Ctenolabrus and Tautoga.	None.	June to Sept.?	...	Agassiz Young Stages, etc., Part II. Flounders, Pl. VI. figs. 5–7. Figs. 1–4 = Tautog. Stein. Mass. Fish Rep., 1872, p. 47. Storer. Hist. Fishes Mass., Pl. XXXI. fig. 2.
Rhombus maculatus, Mitch.	...	...	...	...	...	Agassiz. Young Stages, etc., Part II., Pl. V., pp. 6–13, Pls. VII., VIII.
Pseudorhombus oblongus, Stein.	...	...	...	...	...	Agassiz. Young Stages, etc., Part II., Pl. IX. figs. 4–7.
Plagusia sp.	...	...	...	...	...	Agassiz. Young Stages, etc., Part II., Pl. X. Emery. Real. Acad. d. Lincei, 1883 (Rhomboidichthys). Steenstrup, *loc. cit.*
Labrax lineatus, Bl. Sch.	...	...	...	...	...	Agassiz. Young Stages, etc., Part III., Pl. I.
Cyclopterus lumpus, Lin.	...	...	...	...	...	Agassiz. Young Stages, etc., Part I., Pl. II. fig. 6; Part III., Pls. IV., V.
Poronotus triacanthus, Gill.	...	...	...	...	...	Agassiz. Young Stages, etc., Part III., Pl. VI. Lütken, Spolia Atlantica.
Gasterosteus aculeatus, Lin.	...	...	...	...	...	Agassiz. Young Stages, etc., Part I., Pl. II. figs. 13, 14; Part III., Pl. IX. Huxley. Tail of Gasterosteus, Mic. Jour.
Atherinichthys notata, Günt.	...	...	...	...	...	Agassiz. Young Stages, etc., Part III., Pls. X., XI.
Batrachus tau.	...	...	...	...	...	Agassiz. Young Stages, etc., Part III., Pl. XVI. fig. 1.
Gadus morrhua, Lin.	...	...	...	...	...	Agassiz. Young Stages, etc., Part III., Pl. VIII. figs. 4, 5. See also Sars, G. O.; Ryder, U. S. Fish Commis. Report.

EXPLANATION OF THE PLATES.

PLATE I.

Cottus grœnlandicus, C. & V.

Figs. 1-5.

Figs. 1, 2, 3. Three eggs in nearly the same stage of development, showing a variable number of oil-globules, and the distribution and color of the pigment. Magnified about 50 diam.

Fig. 4. Just hatched. Possibly a different species. × 55.

Fig. 5. A few hours after hatching. Has fewer pigment-patches on the embryonic fold than the specimen described by Agassiz (Young Stages, etc., Pl. III. Figs. 2, 3) Round fleshy pectorals prominent. × 55.

Species No. 28.

Figs. 6–8.

Fig. 6. An egg taken August 15, 1884, measuring only .63 × .65 mm. × 55.

Fig. 7. Just hatched. × 55.

Fig. 8. Probably a little older, and possibly not belonging to the same species. Vent lateral. × 55.

PLATES II. and III.

Species No. 26.

Figs. 1–3.

Fig. 1. Egg of some species of Motella, found July 25, 1884.

Fig. 2. A later stage, found at the same time. × 55.

Fig. 3. Young at time of hatching, showing the position of the lateral-line organs, the lateral nerve, and three cranial nerves supplying the lateral-line organs of the head. × 55.

Hemitripterus americanus, C. & V. (**H. acadianus,** Storer.)

Figs. 4–12.

Figs. 4, 5. Two eggs in about the same stage of development, but showing some differences in color. Head remarkably wide.

Fig. 6. A somewhat later stage, after the pigment-cells have spread over the whole yolk-sac.

Fig. 7. Just before hatching.

Fig. 8. Twelve hours after hatching. Arch of the dorsal fold unusually high. The three pigment-patches on the fold are characteristic of this species.

Fig. 9. Thirty-six hours old.

Fig. 10. A much later stage, showing the thickening along the dorsal line, which represents an early stage in the development of the dorsal fins. Remarkable for its light color.

Fig. 11. A somewhat older fish, showing a more advanced stage of the dorsal thickenings. The embryonic fold much reduced.

Fig. 12. A similar stage, in which the dorsal thickenings are not yet distinctly marked.

PLATES IV. AND V.

Temnodon saltator, LIN. (**Pomatomus saltatrix**, GILL.)

Fig. 1. Profile view of the early ring stage, treated with osmic acid and chrome-platinum solution. × 55.

Fig. 2. Same, seen from above. × 55.

Fig. 3. Just after closing of the blastopore, showing the peripheral arrangement of the yolk-segments. ×55.

Fig. 4. A somewhat older stage, seen from the ventral side.

Fig. 5. A section of the yolk-sac at the stage of Fig. 3, showing the two strata of the ectoderm (*ec*), the thin periblast (*p*) and the yolk-segments (*ys*).

Fig. 6. Stage shortly before hatching.

Fig. 7. Just hatched. Yolk-segments are still quite distinctly seen.

Fig. 8. Thirty-six hours old. Yellow pigment has reached its maximum point of development.

Fig. 9. Sixty hours old.

Fig. 10. Eighty hours old.

Fig. 11. Nine days old.

Fig. 12. A later stage, showing the muscular thickenings for the posterior dorsal and the anal, and the bilobed heterocercal stage of the tail.

Fig. 13. A stage still farther advanced in the development of the unpaired fins.

Fig. 14. Permanent rays appear in the dorsal and anal. The permanent caudal appears like a second anal.

Fig. 15. Young fish measuring 9 mm. in length. The embryonic lobe has disappeared, and the caudal has assumed the homocercal form.

PLATE VI.

Lophius piscatorius, LIN.

Fig. 1. The egg magnified 25 diameters.

Fig. 2. Three eggs enclosed in saccular spaces of the mucous band.

Fig. 3. Showing natural size of the eggs.

Figs. 4–7. Different views of the unhatched embryo.

Fig. 8. Portion of the embryo and the yolk-sac, showing the character of the pigment.

Fig. 9. Frontal view of the embryo.

Fig. 10. One of the chromatophores of the yolk-sac enlarged.

PLATES VII.–IX.

Ctenolabrus adspersus, WALB. (**C. cœruleus**, STORER.)

FIGS. 1–34. × about 50.

Fig. 1. The freshly laid egg, before fecundation. Quite opaque from the presence of numerous highly refractive granules in the peripheral layer of the yolk.

Fig. 2. Profile view of the fecundated egg, showing the blastodisc.

Fig. 3. Same, seen from above.

Fig. 4. The two-cell stage from above.

Fig. 5. Four-cell stage in profile.

Fig. 6. Eight-cell stage in profile.

Fig. 7. Same, from above.

Fig. 8. Sixteen-cell stage, seen from above.

Fig. 9. In the same stage as Fig. 8 after the disappearance of the nuclei.

Fig. 10. The eight-cell stage in process of dividing.

Figs. 11, 12. Two examples of the sixteen-cell stage, in one of which a wavy line separates the four central cells from the twelve marginal ones.
Fig. 13. A stage of from thirty-two to sixty-four cells.
Fig. 14. A similar stage, showing many of the marginal cells in a state of division.
Fig. 15. A slightly older stage.
Fig. 16. Same, seen from the side.
Fig. 17. A still more advanced stage of cleavage.
Fig. 18. The blastodisc is split up into very small cells, with a wreath of periblastic nuclei around it.
Fig. 19. An early stage of the embryonic ring.
Fig. 20. Profile view of the disc at the time the ring begins to form.
Fig. 21. The axial plate appears at one point of the ring.
Fig. 22. The ring has now attained its full width, and the embryonic plate is much larger.
Fig. 23. Embryonic plate still longer, and the ring advanced to an equatorial position.
Fig. 24. The embryonic plate seen from above, just after the ring has passed the equator of the egg. Chorda broad behind, the boundary lines vanishing before reaching the caudal lobe.
Fig. 25. Embryonic ring well advanced ; optic vesicles forming.
Fig. 26. Profile view just after the closing of the blastopore. Kupffer's vesicle still prominent.
Fig. 27. The caudal end already well formed; black pigment-dots appear in two lateral lines.
Fig. 28. A later stage, showing a comparatively thick embryo, with somewhat larger pigment-dots.
Fig. 29. A still more advanced embryo.
Fig. 30. Just before hatching. Yolk-sac already considerably reduced in size.
Fig. 31. Embryo seen from above at the time of hatching. Pigment extends to end of tail, but only two dots seen on the head.
Figs. 32 and 33. Two views of the same embryo, some hours after hatching; the chromatophores have assumed the dendritic form, and are much more prominent than in Fig. 31.
Fig. 34. A profile view of a young fish about twenty-four hours old. The embryonic fold is remarkably narrow on the anterior part of the body.

PLATES X. and XI.

Tautoga onitis, Lin. (**T. americana**, Storer.)

Fig. 1. The egg shortly after the closing of the blastopore. From a batch of eggs artificially fertilized. × 55.
Fig. 1 *a*. Middle portion of another embryo of the same stage, showing fewer pigment-dots.
Figs. 2 and 3. Similar portions of different embryos more highly magnified, to show the character of the pigment. × 130.
Fig. 4. Profile view at time of hatching. × 55.
Fig. 5. A portion of Fig. 4 more highly magnified. × 130.
Fig. 6. Frontal view of Fig. 4.
Fig. 7. Frontal view twenty-four hours after hatching. Pigment-cells expanded. ×55.
Figs. 8 and 9. Profile and frontal views of a specimen one to two days old.
Fig. 10. Two days old. Snout more pointed than in preceding stage, embryonic fold narrower. Same as Fig. 2, Pl. VI., in Agassiz's "Young Stages," etc. (II. Flounders).
Fig. 11. = Agassiz's Fig 3 of the same Plate. Snout still more prolonged ; tail shows a tendency to heterocercality.
Fig. 12. = Agassiz's Fig. 4 of the same Plate. Somewhat older stage. Body greatly increased in width, air-bladder prominent, tail more decidedly heterocercal.

PLATES XII. and XIII.

Species Nos. 1, 2, 15.

Fig. 1. The egg just after the closing of the blastopore. × 55.
Fig. 2. Eighteen hours later. Chromatophores very large. × 55.

Fig. 3. Just before hatching (forty-two hours after Fig. 1). × 55.
Fig. 4. A somewhat younger stage than Fig 2, showing two oil-globules.
Fig. 5. Same, somewhat later, after coalescence of the globules.
Fig. 6. Profile view at time of hatching. × 55.
Fig. 7. Similar view of another individual, showing the lateral-line organs and the lateral nerve. × 55.
Fig. 8. Seen from the dorsal side, showing lateral-line organs of both sides.
Fig. 9. Twenty-four to thirty-six hours old.
Fig. 10. Frontal view of a specimen twelve hours old.
Fig. 11. Profile view of the same.
Fig. 12. Twelve days old (oldest raised from the egg).
Fig. 13. A later pelagic stage. Embryonic fold much reduced.
Fig. 14. Still more advanced pelagic stage.
Fig. 15. The oldest pelagic stage.

PLATES XIV. AND XV.

Pseudorhombus oblongus, Storer (Pl. XXXI. Fig. 3).

Fig. 1. An egg at the time the blastopore closes, before any pigment has appeared in the chromatoblasts.
Fig. 2. A little later stage, in which Kupffer's vesicle is disappearing. Chromatoblasts still colorless.
Fig. 3. Minute round black pigment-dots have now appeared in some of the chromatoblasts. Yellow pigment just begins to appear on the body.
Fig. 4. Somewhat later; the yellow pigment, now more pronounced, has the form of round cells in the region of the tail, but appears in diffuse yellow stains farther forward.
Fig. 5. Just before hatching. Yellow pigment less abundant than in most eggs of this stage.
Fig. 6. Young Flounder, twelve hours old. Yellow pigment has become reddish brown on the embryonic fold, and concentrated into patches; that of the body is evenly diffused. The black cells are dendritic and unusually prominent.
Fig. 7. Thirty-six hours old. Both black and yellow pigment-cells are in a state of semi-expansion.
Fig. 8. Sixty hours old. Gives the more typical arrangement of the yellow patches, here dusky buff.
Fig. 9. A dorsal view of the head at the same age, showing that it is still symmetrical.
Fig. 10. About three days and a half old. This specimen and that of Fig. 8 were taken at Nahant.
Fig. 11. Sixty hours old.
Fig. 12. Somewhat older stage than Fig. 11. The black spots are more closely packed along the lower side of the axis, with more numerous dendritic spokes. The single patch of black spots half-way between the vent and the extremity of the tail fin very marked.
Fig. 13. Still older stage than Fig. 12. The right eye is no longer symmetrically placed; the black spots, with the exception of the caudal patch, are arranged in a close line along the lower side of the muscular axis, the upper part of the anterior portion of the chorda, and the lower edge of the stomach.
Fig. 14. Slightly older stage than Fig. 13. The chromatophores are contracted to mere dots, while they are fully expanded in the preceding stage. The embryonic fins of the last two stages have become comparatively narrower. The yellow spots now form two large patches, one along the upper part of the stomach, the other over the caudal patch.

PLATE XVI.

Pleuronectes americanus, Walb.

Fig. 1. An exceptionally small egg (.70 × .73 mm.) doubtfully classed with the following stages. The figure shows the embryo shortly after the closure of the blastopore, and represents one of the earliest stages in the development of the chromatophores. × 55.
Fig. 2. A somewhat younger stage, in which the blastopore has just closed, showing the first appearance of pigment-dots.
Fig. 3. A later stage, in which the pigment is more perfectly developed.

Fig. 4. Near the time of hatching.
Fig. 5. Young Flounder, twelve hours old, seen from ventral side.
Fig. 6. A profile view of a specimen, about thirty hours old, showing a variation from the more typical pigment-marking seen in the following figure.
Fig. 7. Of the same age as Fig. 6, but with a more characteristic arrangement of pigment-spots.
Fig. 8. About sixty hours old. Yolk-sac has nearly disappeared. Four well-marked pigment-patches. Eye green with coppery reflection.
Fig. 9. About eighty-four hours old. Pigment nearly the same as in Figs. 8 and 10. The granular surface is here more fully represented than in the other figures.
Fig. 10. Eighty-four hours old.

PLATE XVII.

Species No. 10.

Figs. 1–3.

Fig. 1. Shows the character and distribution of the pigment in the embryo shortly before hatching. Supposed to belong to the same species as Figs. 2 and 3. × 55.
Fig. 2. Represents a young fish not less than three or four days old.
Fig. 3. A later stage, in which the vent has taken a marginal position, and the black chromatophores have become very large and conspicuous.

Osmerus mordax, Gill.

Figs. 4–6.

Fig. 4. Supposed to be the egg of *Osmerus mordax*, Gill. The entire yolk is segmented. The embryo is long and slender, and shows no trace of pigment.
Fig. 5. Just hatched, measuring 5 mm. in length, seen from above.
Fig. 6. Same, seen in profile.

PLATE XVIII.

Motella argentea, Rhein.

Figs. 1–6.

Fig. 1. An egg at the time when the blastopore is nearly closed. The chromatoblasts are beginning to appear, but as yet there is no trace of pigment. × 55.
Fig. 2. The same, six hours later. Granules of black pigment appear in the chromatoblasts. × 55.
Fig. 3. The same, twenty-four hours later. Dendritic chromatophores more numerous on the body than on the yolk. × 55.
Fig. 4. The same, twenty-four hours later. × 55.
Fig. 5. Just before hatching (twenty-four hours later than Fig. 4). Arrangement of pigment now anticipates the more advanced stage of concentration in definite regions, seen in Fig. 6. × 55.
Fig. 6. Twelve hours after hatching. Eye is black.

Species No. 23.

Figs. 7–10.

Fig. 7. Represents the earliest stage obtained. Four pairs of yellow pigment-clusters characterize this egg. × 55.
Fig. 8. At the time of hatching. × 55.
Fig. 9. Thirty-six hours old. Pigment in a state of expansion.
Fig. 10. Three days old. Yellow pigment much reduced.

PLATE XIX.

Species No. 25.

Figs. 1–7.

Fig. 1. Just after the closing of the blastopore. Two kinds of pigment already richly developed, but wholly confined to the embryo. The three globules coalesce in the course of a few minutes. × 55.

Fig. 2. Eighteen hours later. A concentration of the yellow pigment in certain regions begins to manifest itself. The black chromatophores are fewer in number than in the preceding stage. × 55.

Fig. 3. Just before hatching. No trace of pigment on the yolk. × 55.

Fig. 4. Just hatched. The dull brownish-yellow pigment in a state of expansion; it is somewhat denser in regions more clearly defined in Fig. 5.

Fig. 5. Twenty-four hours old.

Fig. 6. Seventy-two hours old. Yellow pigment much increased on the reduced yolk-sac, as well as on the head and fore part of body.

Fig. 7. Four days old. Most of the pigment has disappeared.

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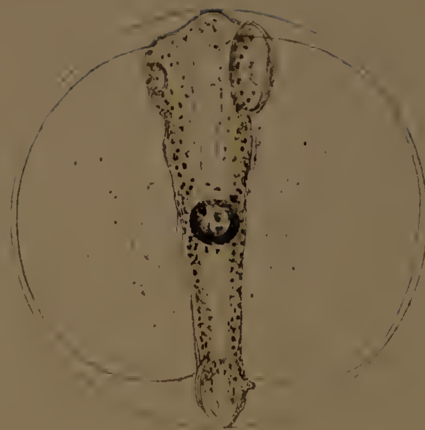

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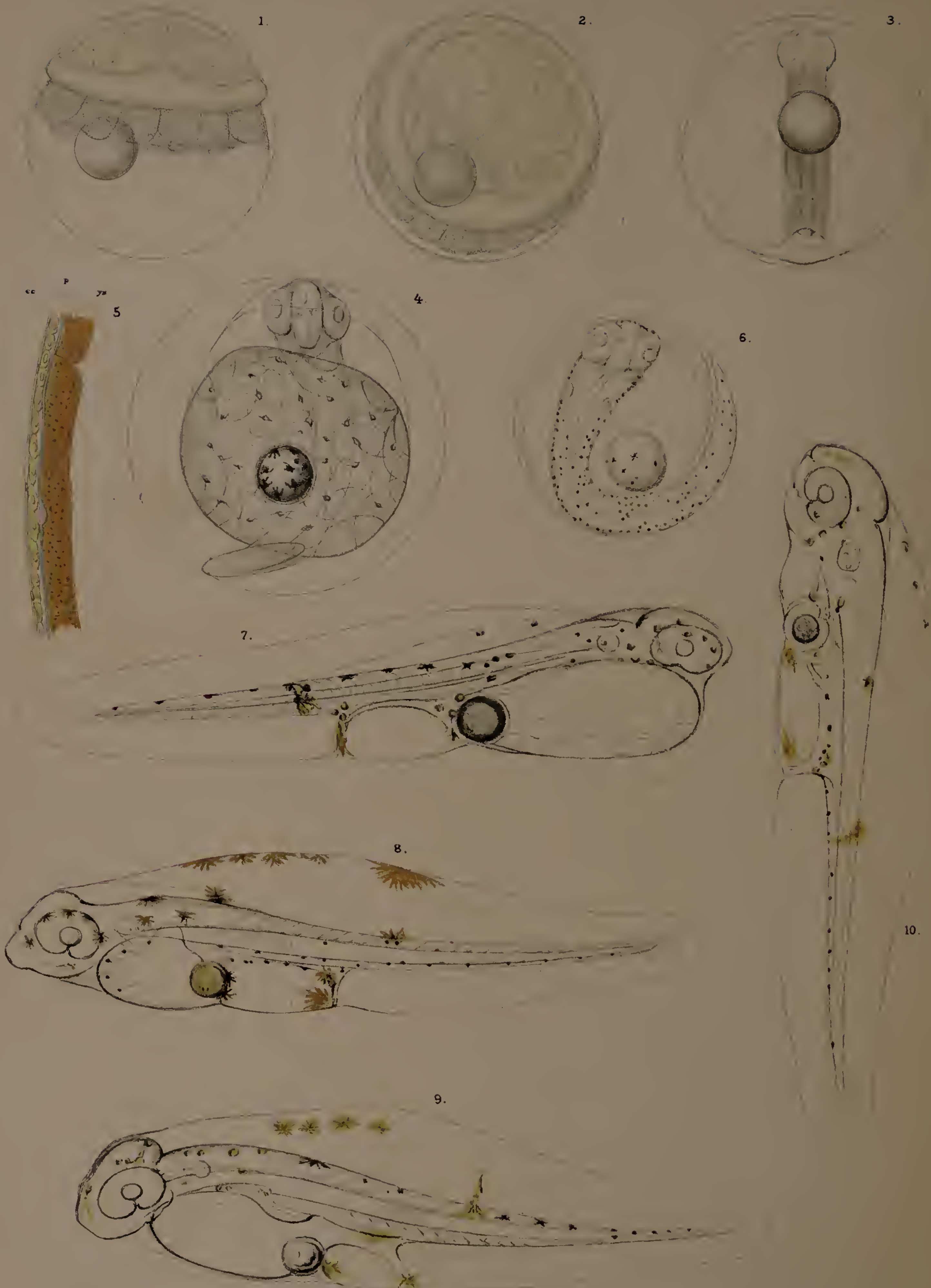

Agassiz and Whitman, del.

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